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# Concept Evaluation Report. Taconite Tailings Disposal. Reserve Mining Company, Silver Bay, Minnesota

Roy F Weston, Inc, West Chester, Pa

Prepared for

Environmental Protection Agency, Washington, D C

27 Oct 71

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The Office of Water Programs of the Environmental Protection Agency retained ROY F. WESTON to develop conceptual methods for treating and disposing of the taconite wastes and to conduct an independent evaluation of feasible wastewater treatment and disposal alternatives. The sections will cover the following: the major issues developed by previous studies of tailings discharges to Lake Superior; technical review of previous proposals for treatment and disposal of taconite tailings; discussion of ROY F. WESTON process investigation and tailings reuse; concept design of various alternatives for tailings processing and disposal; and, the economic and financial impact on Reserve Mining and on the State of Minnesota of implementation of various proposals for taconite tailings disposal.

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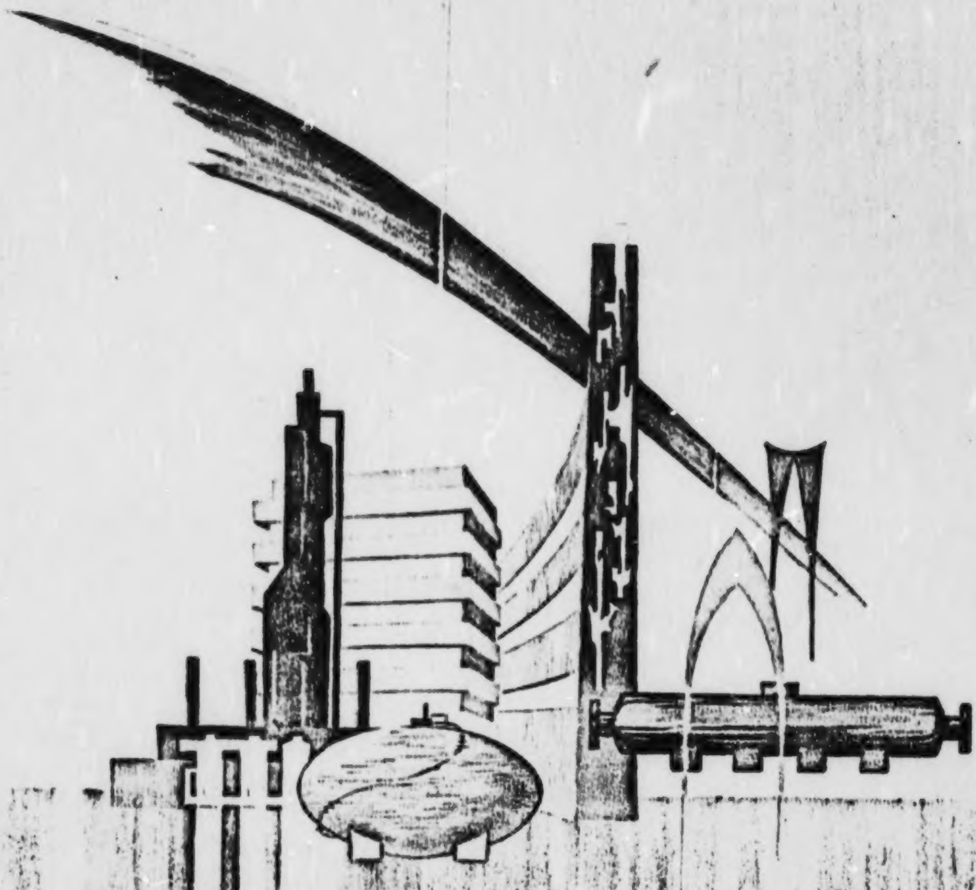
## TACONITE TAILINGS DISPOSAL

RESERVE MINING COMPANY
SILVER BAY, MINNESOTA

PREPARED FOR

ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D. C.



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# Concept Evaluation Report
# Taconite Tailings Disposal

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# SECTION I

# INTRODUCTION

## History of Taconite Mining and Processing Operation[1]

Taconite from the eastern Mesabi Range was first thought to be a useful ore about 1872, even prior to the discovery of the rich hematites of the western range. Work on taconite processing began in 1913 at the University of Minnesota Mines Experiment Station and continued through several pilot and production plants, which were partially successful. The first commercial processing was attempted in 1922 by the Mesabi Iron Company, which produced a sinter with 60 to 64 percent iron and 9 to 12 percent silica. However, ore buyers were not satisfied with the iron content, and the plant closed for economic reasons in 1924.

Work at the University continued with development of process parameters, process equipment, and improved pellet quality, from 1924 through World War II. The drain on western Mesabi ore caused by World War II steel production and the potentially superior blast furnace feed resulting from beneficiation stimulated renewed interest in taconite. The removal of the Ad Valorem tax on taconite and of taxation on the basis of mineral content shipped, removed a potential burden from interested taconite developers in 1941. Shortly thereafter, several companies (Erie Mining, Reserve Mining, Bethlehem Steel, and U.S. Steel) began working independently on beneficiating and pelletizing processes.

## Formation of Reserve Mining Company

Oglebay Norton, an agent for several investors, began organization of a taconite mining enterprise and named it Reserve Mining. The scale of the planned processing plant (an initial production capacity of 3.7 million tons of pellets per year, with expansion capability up to 10 million tons/yr.) required particular attention to the economies of obtaining process water, disposing of tailings, and providing treatment facilities for water reuse. These were major concerns because a plant of this scale would require 45 tons of water per ton of concentrated ore, sufficient area for storage of tailings for 25 to 30 years at 20 million tons per year, and area for a settling basin. Other major considerations were transportation, power, and worker housing costs and investment planning. Because the Reserve mine site at Babbitt, Minnesota had an insufficient water supply and no likely area for a settling basin or other required facilities, the final choice was a process plant location at Silver Bay, with ore transport from the mine to the plant. Map No. 1 shows the general location of the operations involved. Abundant water supply and tailings disposal into Lake Superior promised to minimize operating costs and reduce the risk of investment.

Land purchases were completed in 1948, after hearings for tailings discharge permits were held throughout 1947 by the Minnesota Department of Conservation and the Minnesota Water Pollution Control Commission. As a result, permission for withdrawal of water from the Lake at the rate of 130,000 gallons per minute and for disposal of tailings into the Lake was granted in December of 1947.

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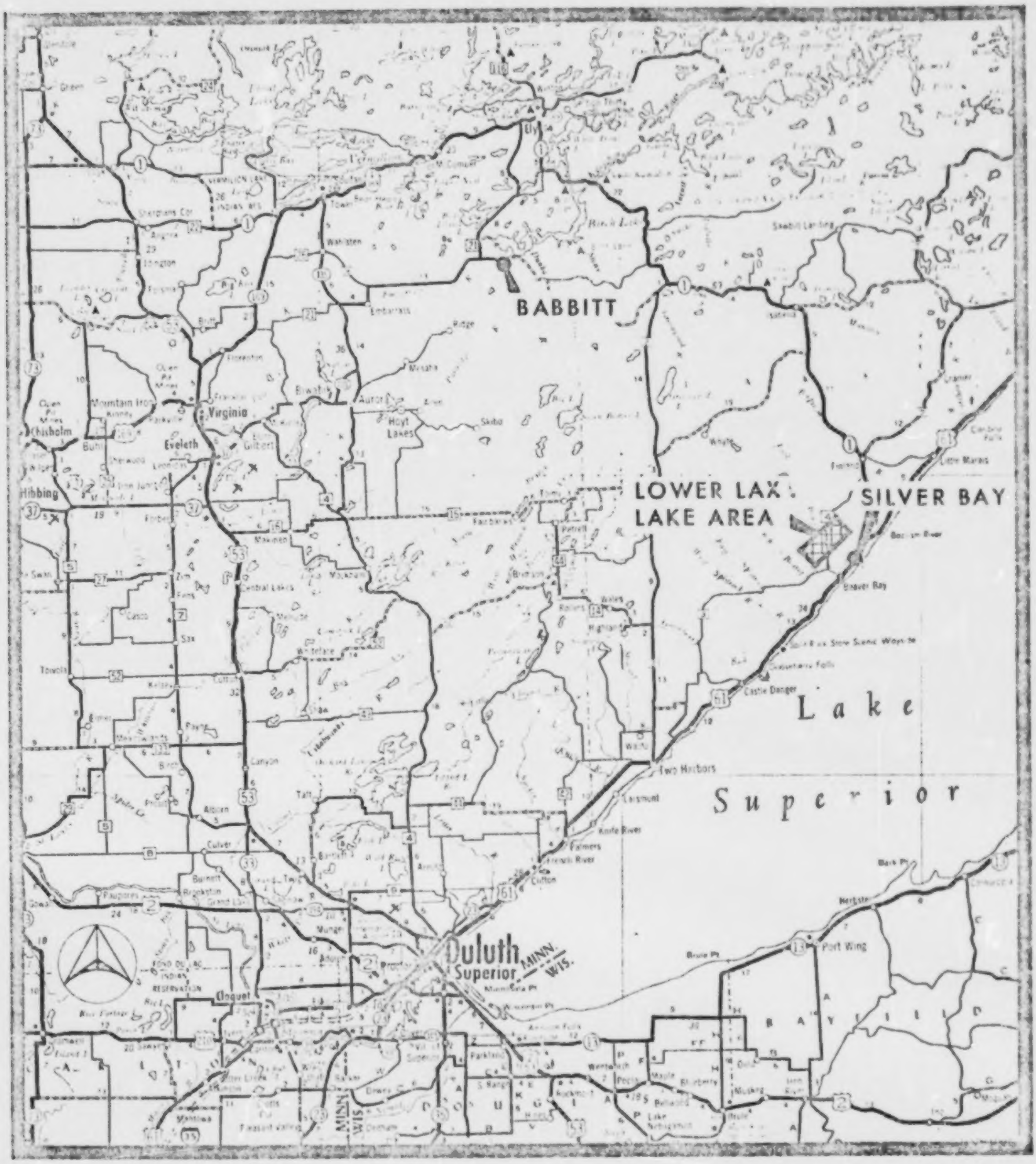
[1] Davis, E.W., "Pioneering with Taconite", Minnesota Historical Society, St. Paul, 1964.

# RESERVE MINING COMPANY
# SILVER BAY, MINNESOTA

## GENERAL LOCATION MAP


BABBITT
Virginia
Eveleth
Hibbing
Chisholm
Hoyt Lakes
LOWER LAX LAKE AREA
SILVER BAY
Beaver Bay
Two Harbors
Lake Superior
Duluth
Superior
MINN. WIS.
Cloquet
Port Wing
Scale 0 5 10 20 30 miles
One inch equals approximately 14 miles

1a

MAP 1

With the granting of the discharge permit, Oglebay Norton had brought together all aspects of the plan, and in 1950 sold all rights to Armco Steel and Republic Steel Corporations, both of whom had a strong interest in integrating their steel-making process. The implementation of this plan at that time was economically significant for Minnesota because the alternate choice for interested corporations was to await development of Labrador ore supplies. The use of Labrador ore would necessitate transport of the Canadian ore through the St. Lawrence Seaway, and would cause a substantial loss of revenue in Minnesota.

Armco and Republic announced their plan to construct a plant of 3,750,000 tons initial capacity in September of 1951. In the first full year of operation (1956), Reserve Mining produced approximately 3.7 million tons of pellets. With process modifications, the plant was producing approximately 6 million tons per year by 1961.

The advantage of 100 percent pellet charge in blast furnaces became apparent after Armco Steel Corporation conducted large-scale tests in 1960 to define operating parameters. It was found that existing blast furnace capacity could be increased nearly 100 percent with the taconite pellet charge and an increased air supply. Shortly thereafter, a 3-million-ton per year expansion of the Reserve operation was announced. Production capacity has increased again since 1967, and currently is between 11 and 12 million tons per year. Total investment currently is approximately $350,000,000.

Current production is 30,000 tons per day of finished pellets. The beneficiating process utilizes grinding and magnetic separation of the iron fines. About 67,000 tons of tailings are washed out of the process using about 500 million gallons of Lake Superior water on a once-through basis. Under the terms of the permits issued by the U.S. Army Corps of Engineers and the State of Minnesota, the tailings are discharged without treatment by means of two launders or troughs which have been extended, over the years of operation, across a broad delta out into the Lake. The delta has been formed by the large size tailings as they settle out of the launder discharge. The smaller tailings remain suspended in the launder effluent and are carried into Lake Superior.

Discharge and permit renewals were questioned in 1967, when the Corps of Engineers and the Department of the Interior formed a study group to respond to the question of the environmental effects of continued tailings discharge to Lake Superior (the largest and purest fresh water lake in the United States). Subsequent Department of the Interior studies resulting from action by the Secretary of the Interior under the provisions of Section 10 (d) (1) of the Federal Water Pollution Control Act, led to the convening of the Lake Superior Enforcement Conference in May of 1969.

In July 1969, the Minnesota Pollution Control Agency requested that Reserve Mining comply with Regulation WPC 15. In December, 1969 Reserve filed a notice of appeal, and a trial was held at Two Harbors from June 22 to October 2, 1970. Judge Eckman's decision of April, 1971 is currently under appeal by the Minnesota Pollution Control Agency.

The original Lake Superior Enforcement Conference was reconvened in April and August of 1970 and again in January and April of 1971. At the conclusion of the August 1970 Session, the conferees requested Reserve Mining to submit preliminary plans for pollution abatement by December 1, 1970 and to develop final plans and specifications by September 1, 1971.

Prior to the submission of a disposal plan, Reserve Mining had considered 19 alternatives, ranging from complete on-land tailings disposal to modification of the in-lake discharge scheme. Following a review of the preliminary plans at the April 1971 Session, the Technical Committee determined that Reserve Mining's "Plan to Modify Tailings Discharge System" (a completely in-lake disposal system) was unacceptable.

As a result of the April, 1971 Conference Session, the Administrator of the Environmental Protection Agency, William D. Ruckelshaus, notified the President of Reserve Mining, Edward M. Furness, that the Company was in violation of established State and Federal Water Quality Standards and that the firm had 180 days to resolve the problem prior to action by the Environmental Protection Agency in accordance with Section 10 (g) of the Federal Water Pollution Control Act.

## Scope and Objectives of Study

In view of the studies conducted and alternatives proposed to date, the Office of Water Programs of the Environmental Protection Agency has retained ROY F. WESTON to develop conceptual methods for treating and disposing of the taconite wastes and to conduct an independent evaluation of feasible wastewater treatment and disposal alternatives.

The philosophy insisted upon and maintained by ROY F. WESTON throughout this project was indicated in the ROY F. WESTON proposal of 19 April 1971.

> "Roy F. Weston, Inc. believes that the approach to this problem should be as though we were retained by the industry to develop the most economical and feasible alternative for wastewater treatment and disposal consistent with the 'conference' objectives for protecting the environment."

Cont'l
√4

The general scope of this project under terms of Contract No. 68-01-0131 and subsequent agreements between the Federal Government and ROY F. WESTON consists of:

1. Collection and review of all available pertinent information and data from correspondence, prior studies, reports, and conference proceedings.

2. Comparison of all previously proposed treatment and disposal schemes on the basis of economics and environmental impact.

3. Analysis of Reserve Mining and other similar ore-beneficiation operations to determine the impact of the various processes on the wastewater characteristics, quantities, and variability, noting techniques or methods to reduce wastewater quantities for future consideration.

4. Determination of optimum treatment parameters, including flocculant dosages, settling velocities, and solids thickening and dewatering characteristics, on individual process streams and/or combined effluents, using physical and chemical laboratory-scale treatability tests.

5. Development of conceptual treatment processes or methods for handling taconite wastes based on parameters established in the previous steps, including the application of feasible in-plant modifications and utilization of tailings for constructive purposes.

cont'd from P. 2

6. Evaluation of the long-range impact of tailings disposal alternatives on the environment.

7. Review and analysis of economic and financial considerations relative to the overall waste treatment objectives and the future of taconite processing.

The overall objective of this assignment is to develop minimum cost solutions consistent with the conference guidelines for protecting the environment in general and for conformance to the federally-approved "Specific Standards of Quality and Purity for Lake Superior" (contained in WPC 15) in particular. The limits or ranges of the various contaminant substances specified in "Specific Standards of Quality and Purity for Lake Superior" are shown in Appendix E.

the following

It should be noted at this point that the assignment essentially was presentation of an impartial evaluation rather than development of specific conclusions and recommendations. The following sections ~~will~~ cover: the major issues developed by previous studies of tailings discharges to Lake Superior; technical review of previous proposals for treatment and disposal of taconite tailings; discussion of ROY F. WESTON process investigation and tailings reuse; concept design of various alternatives for tailings processing and disposal; and the economic and financial impact on Reserve Mining and on the State of Minnesota of implementation of various proposals for taconite tailings disposal.

# SECTION II

# IMPACT OF TAILINGS DISCHARGE INTO LAKE SUPERIOR

## Problem Definition

To comply with the overall objective of the assignment, it is necessary to identify the nature of the pollution control problem compare different pollution control alternatives, and identify those alternatives that can be expected to meet the EPA requirements.

The nature of the problem has been identified by a detailed review of the various research studies, testimony at hearings, private studies, and proceedings of the Lake Superior Enforcement Conference (1969-1971), and by in-plant studies and wastewater treatment investigations. ROY F. WESTON does not purport in this section to render judgment on the efficacy or credibility of the studies, hearings, or proceedings that were reviewed. The major hearings, proceedings, and studies reviewed were:

a. The Initial 1947 Permit Hearings
b. The Minnesota WPCC Startup Conference of 1955
c. Reserve Mining Impact Study of 1956
d. The Minnesota WPCC Fisherman's Hearing of 1956
e. The Study of Limnology and Currents of 1956-58
f. Taconite Residual Studies of 1959
g. Joint Taconite Group Study of 1967
h. Minnesota Joint Agency Study of 1968
i. Proceedings of Enforcement Conference on Pollution of Lake Superior, 1969-71
j. Studies Conducted by Reserve Mining
k. The report of the Environmental Protection Agency issued June 3, 1971 and entitled "Informal Hearing on Alleged Violations of Lake Superior Water Quality Standards by Reserve Mining Company, Silver Bay, Minnesota".

ROY F. WESTON has not reviewed the most recent Lake studies being conducted by Region V of the Environmental Protection Agency.

## Summary of Major Issues

On the basis of a detailed review of previous studies, testimonies, and proceedings the following facts and/or allegations may be determined to be significant:

1. Approximately 67,000 tons per day of taconite tailings are discharged to Lake Superior, as a slurry, in approximately 500,000,000 gallons of water. Normally, this slurry has a temperature range of approximately 4 to 20°C and contains 4 to 5 percent suspended solids varying in particle size from 3/8 inch to less than 1 micron.

2. The wastewater slurry behaves as a density current and deposits its contents along the face of the tailings slope and on the bottom of the lake. At times, elevated wastewater temperature and strong thermoclines are instrumental in stripping fines from the density current and dispersing them into the upper water layers. There is evidence that so-called "green water" occurs at such times. Wave action and surface currents keep the particles in suspension and aid in transporting them.

3. The water-borne materials discharged into Lake Superior from Reserve Mining's Silver Bay beneficiation plant are conservative in nature. Therefore, these materials continually accumulate as sediment, concentrate as dissolved salts or as a suspension, or increase as recycled elements.

4. Lake currents in the area of Reserve Mining are alleged to proceed generally in a counterclockwise flow southwest along the Minnesota shore to Duluth and then northward along the Wisconsin shore. These lake currents assist in carrying the fine portion of the discharge slurry over a bottom deposit area allegedly extending approximately 8 miles out into the lake and approximately 20 miles southwest toward Duluth.

   It is alleged that cummingtonite, an element in the tailings used to trace Reserve's discharge, has been found in bottom core samples outside of the permit area and also in Wisconsin waters. Stream sources in Wisconsin and Minnesota, however, may also contribute some part of the cummingtonite found in the various samples.

5. A 3-month study on the solubility of tailings in lake water indicated low absolute solubility but showed that the relative concentrations of iron and manganese increased appreciably. The solubility potential of tailings particles should be directly related to the surface area of the given particle relative to its weight. Consequently, fine tailings would have a significantly higher potential for leaching than would an equivalent weight of larger tailings.

6. Laboratory experiments indicated that algal growth was stimulated as a result of nutrient increase from the tailings discharge.

7. Laboratory studies indicated that low tailings concentrations promote bacterial growth. Some fishermen have reported slime growths (in their nets downstream from Reserve Mining) that contain iron-fixing bacteria.

8. Some fish toxicity tests showed that fish cannot live in the high-density slurry discharge. However, it is alleged that no adverse effects were observed at reasonable dilution of the slurry, and no adverse effects on fish in the lake are traceable to tailings discharge.

9. Bottom fauna studies indicated that Ponporoneia (bottom shrimp) populations southwest of the Reserve plant were approximately 50 percent lower than the Ponporoneia northeast of the plant. The observation did not account for differing bottom characteristics.

## SECTION III

## REVIEW OF PREVIOUS TAILINGS DISPOSAL INVESTIGATIONS

### Background

In April of 1969, Reserve Mining Company announced the formation of an engineering task force to investigate and study possible alternatives for altering or modifying its discharge of tailings to Lake Superior. The task force was composed of Reserve engineers and scientists, and five nationally known engineering consulting firms.

In all, nineteen separate approaches were investigated by this task force. These approaches, which are summarized in Table 1, served as the basis for Reserve's "Plan to Modify Tailings Discharge System", which was officially presented at the Lake Superior Enforcement Conference. This plan is presented as Proposal No. 20 in Table 1.

A preliminary review of these alternatives revealed a great diversity of design basis and design objectives. For example, four different methods of tailings transport were proposed, five separate sites for tailings disposal were studied, and several methods of discharging tailings to Lake Superior were offered. Because of these differences, it was difficult to make direct comparisons of the alternatives to determine their relative economic and technical merits. In general, however, all the alternatives were composed of basic operations which, when isolated from each alternative, provided some basis for comparison.

In the sections which follow, comparisons are made concerning the technical and economic characteristics of each proposal. The more significant differences are discussed in some detail.

### Basis for Comparison

In an effort to offer a rational basis for comparison, each of the proposals mentioned in Table 1 has been broken down into four major operations:

1. In-plant alterations
2. On-site wastewater processing
3. Tailings transport system
4. Final disposal of tailings

The involvement of these operations in each proposal is listed in Table 2.

In-plant alterations deal with recommended changes to the existing beneficiation plant to provide for more efficient waste handling. On-site wastewater processing concerns the necessary facilities to separate the tailings from the process water. It is assumed that on-site processing will take place on the tailings delta at Silver Bay. Tailings transport systems include pressure pipelines, overland belt conveyors, rail haul, and gravity discharges to Lake Superior. In some cases, more than one system has been employed in a specific alternative. The final disposal operation deals with the end point of the respective transport system. The Lax Lake area or Lake Superior provides the final disposal point in most of the proposals. The remaining disposal points are included under the "other" category of Table 2.

## Table 1

## Summary of Tailings Disposal Alternatives Investigated by Reserve Mining Task Force

| Proposal No. | Primary Investigator | Description |
|---|---|---|
| 1 | Trygve Hoff & Associates | Overland pumping of all tailings to man-made tailings impoundment in Lax Lake Area. |
| 2 | Trygve Hoff & Associates | Rail haul of all tailings to Babbitt for on-land disposal south of Taconite mine. |
| 3 | Trygve Hoff & Associates | Overland pumping of fine tailings (- 150 mesh) to Lax Lake Area for impoundment while coarse tailings (+ 150 mesh) are discharged across delta and into Lake Superior, as is present practice. |
| 4 | Trygve Hoff & Associates | Fine tailings are discharged into Lake Superior at a minimum depth of 150 feet while coarse tailings are discharged across delta and into Lake Superior as is present practice. |
| 5 | Trygve Hoff & Associates | All tailings discharged to Lake Superior behind an impervious 100'-deep curtain forcing tailings to seek lake bottom. |
| 6 & 7 | Bechtel Corporation | Overland pumping of fine tailings (- 35 mesh) to proposed Lax Lake Area impoundment while coarse tailings are separated and hauled by rail to Lax Lake Area. Proposal No. 6 offers year-round rail haul of coarse tailings while Proposal No. 7 provides for rail haul only during summer months. |
| 8 & 9 | Bechtel Corporation | Same as above only coarse tailings are transported to Lax Lake Area utilizing a belt conveyor. Proposal No. 8 provides for full-year operation of conveyor, while Proposal No. 9 offers a 1/2-year or summer months operation. |
| 10 & 11 | Bechtel Corporation | Same as previous alternatives, except that coarse tailings are railhauled to a land disposal site at a point 32 miles northwest of the Silver Bay plant. Proposal No. 10 provides for year-round operation, while Proposal No. 11 investigates coarse tailings disposal during summer months. |
| 12 | Engineering-Science, Inc. | Fine tailings (- 500 mesh) discharged into Lake Superior at a minimum depth of 300', while coarse tailings are discharged across delta into Lake Superior as is present practice. (No report) |
| 13 | Parsons-Jurden Corporation | Tailings will be used to construct a Lake Shore tailings impoundment, to prevent discharge of tailings to Lake. |
| 14 | Parsons-Jurden Corporation | Fine tailings (- 150 mesh) discharged into Lake Superior at a depth of 150', while coarse tailings are discharged across delta into Lake Superior as is present practice. |
| 15 | Parsons-Jurden Corporation | Tailings discharged to Lake Superior at 140' depth without separation. |
| 16 | Reserve Mining Company | Tailings used to construct small boat harbor and swimming area between Mattson's Point and Gull Island. (No report) |
| 17 | Trygve Hoff & Associates | Utilization of dry cobbing for Rod Mill Feed to reduce tailings in discharge to Lake by 30 percent. |
| 18 | Trygve Hoff & Associates | Utilization of screening of ore feed to Rod Mills to reduce the top particle size of tailings and improve tailings process. (No report) |
| 19 | Arthur D. Little, Inc. | Explores market potential for tailings as sand and fine aggregate for construction industry. |
| 20 | Reserve Mining Company | Modified plan to discharge all tailings to Lake Superior at a minimum depth of 150' below surface. |

Table 2

Summary and Comparison of Operational Alternatives Offered
by 19 Disposal Proposals Prepared for Reserve Mining Company

| Proposal No. | In-Plant Alterations | On-Site Processing[1] | Tailings Transport System: Pipeline | Tailings Transport System: Conveyor | Tailings Transport System: Railroad | Tailings Transport System: Gravity Discharge | Final Disposal Site: Lake Superior | Final Disposal Site: Lax Lake | Final Disposal Site: Other | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | X | $X^2$ | | | | | X | | |
| 2 | | X | | | $X^2$ | | | | Babbitt | |
| 3 | | X | $X^4$ | | | $X^3$ | X | X | | Coarse Tailings Discharged to Delta |
| 4 | | X | | | | $X^2$ | X | | | All Tailings Discharged at 150' depth |
| 5 | | | | | | $X^2$ | X | | | Fines Discharged at 150' depth under curtain |
| 6 and 7 | X | X | $X^4$ | | $X^3$ | | | X | | Proposal 7 for summer operation only |
| 8 and 9 | X | X | $X^4$ | $X^3$ | | | | X | | Proposal 9 for summer operation only |
| 10 and 11 | X | X | $X^4$ | | $X^3$ | | | X | Mile 32 | Tailings Basin - Proposal No. 11 (1/2-year Operation) |
| 12 | | X | | | | $X^2$ | X | | | Fines Discharged at 300' depth |
| 13 | | X | $X^2$ | | | | X | | | Lake Shore Impoundment |
| 14 | | X | | | | $X^2$ | X | | | Fines Discharged at 150' depth |
| 15 | | X | | | | $X^2$ | X | | | Coarse material (+ 150 mesh) discharged at 150' depth<br>Fine material (- 150 mesh) discharged at optimum depth |
| 16 | | | | | | | | | | Preliminary Study to Develop Small Boat Harbor and Swimming Area |
| 17 | X | X | | | X | | | | | Investigated dry cobbing in-plant - no disposal included |
| 18 | X | X | | | | | | | | Investigation of screening ore ahead of Rod Mill |
| 19[5] | | X | | | | | | | | Preparation of tailings for sale as sand and fine aggregate |
| 20 | | X | | | | $X^2$ | X | | | Plan to discharge all tailings to Lake at depth of 150'. |

[1] X in the processing column includes wastewater treatment and material separation.
[2] Coarse and fine material.
[3] Coarse material.
[4] Fine material.
[5] Proposal 19 concerns processing facilities specifically for preparation of tailings for marketing of sand and fine aggregate materials.

## Technical and Economic Comparisons

### In-Plant Alterations

Only the Bechtel Corporation (in Proposals 6 through 11) recommended in-plant alterations to the existing water treatment system. The six alternatives proposed the removal of all tailings from the cobber magnetic separator sumps. After removal, the tailings would be fed to a spiral classifier, where the coarse tailings (+35 mesh) would be separated out. The coarse tailings would be discharged to a belt conveyor for final disposal and the fines discharged to the launders for transport to the treatment facility. Removal of the coarse tailings from the plant discharge was proposed to reduce the amount of flushing water required to carry the tailings through the plant, and therefore reduce the total plant wastewater flow. A flow reduction of approximately 175,000 gpm would be realized by this method and would mean a substantial reduction in the cost of the on-site processing facilities.

### On-Site Processing

A summary of on-site wastewater processing facilities specified for all the treatment proposals is presented in Table 3. The proposed on-site processing system generally included preliminary treatment to remove the coarser material, followed by a clarification or thickening step to remove the fines. A two-step clarification process was included in eight of the proposals to provide for the more efficient removal of the fines. The addition of flocculating chemicals, for more effective removal of the fines, was recommended in fourteen of the proposals. Flocculating chemicals were recommended in all the approaches which proposed two-stage clarification.

Preliminary treatment facilities were proposed in all the approaches providing on-site processing. These facilities would remove the coarse fraction of the solids from the wastewater in an effort to reduce the wear and load on the mechanical equipment. In most cases, Hydroseparators of various designs were specified for preliminary treatment; however, Proposal 2 called for rectangular drag tanks to remove the coarse tailings. All the proposals utilize gravity settling (after removal of the coarse solids) to remove the fines from the wastewater.

Only one proposal specifically called for dewatering facilities for the tailings. Proposal 2 recommended the use of fourteen disc-type vacuum filters to dewater the tailings prior to their placement in railroad cars. Proposals 6 through 11 indirectly provided dewatering of the coarse tailings; as part of the spiral classifier operation coarse tailings would be discharged from the classifier with 20 to 25 percent moisture. The remaining proposals used water as a carrier for the tailings and therefore did not require dewatering facilities.

In summary, the major difference between the on-site processing systems offered by each of the proposals lies in the basic approach to the problem. An "end-of-pipe" approach was employed in all the proposals except Nos. 6 through 11. The end-of-pipe approach provided little opportunity for cost savings through flow reduction, and, therefore, facilities were sized to handle maximum flows. For this reason, end-of-pipe approaches involved capital cost investments ranging from $11 to $28 million, while proposed in-plant alterations reduced these costs to approximately $6 million in Proposals 6 through 11. It should be noted, however, that when the cost of in-plant alterations is added to the corresponding capital cost for on-site processing, the total cost is increased to approximately $9 million. This permits a cost saving of approximately $2 million over the least expensive of the end-of-pipe approaches.

Table 3

Technical Comparison of On-Site Processing Equipment

| Proposal No. | Preliminary Facilities | 1st Stage Clarification | 2nd Stage Clarification | Flocculant Use Proposed | Tailings Dewatering | Active Clarifier Area sq.ft. |
|---|---|---|---|---|---|---|
| 1 | 2-Hydroseparators (60'ϕ; one is standby)<br>4-Regrind Mills | 3-Thickeners, 480'ϕ | – | Yes | – | 544,000 |
| 2 | 2-Rectangular drag tanks | 2-Thickeners, 454'ϕ<br>2-Thickeners, 416'ϕ | – | Yes | 14-Disc Filters | 596,000 |
| 3 | 1-Primary Hydroseparator | 2-Thickeners, 420'ϕ<br>2-Thickeners, 360'ϕ | 3-Clarifiers, 350'ϕ | Yes | – | 476,000 |
| 4 | 1-Primary Hydroseparator | 2-Thickeners, 420'ϕ<br>2-Thickeners, 360'ϕ | 3-Clarifiers, 350'ϕ<br>3-Clarifiers, 300'ϕ | Yes | – | 476,000 |
| 5 | – | – | – | – | – | |
| 6 through 11 | 2-Primary Hydroseparators, 60'ϕ | 4-Thickeners, 310'ϕ | 2-Clarifiers, 200'ϕ | Yes | –[1] | 304,000 |
| 12 | 2-Scalper Hydroseparators, 50'ϕ | – | – | – | – | |
| 13, 14, & 15 | 2-Conventional Hydroseparators, 125'ϕ | 4-Thickeners, 310'ϕ | – | Yes | – | 304,000 |
| 16 | 2-Scalper Hydroseparators, 50'ϕ | – | – | – | – | |
| 20 | 2-Conventional Hydroseparators, 125'ϕ | 4-Thickeners, 310'ϕ | – | Yes | – | 304,000 |

[1] Coarse tailings are dewatered as part of spiral classifier operation.

NOTE: Final Reports for Proposals 12 and 16 were not prepared. Proposals 17 and 18 deal specifically with in-plant changes, while Proposal 19 deals with a market survey. Proposal No. 5 does not provide on-site processing equipment.

Proposals 1 and 2 would require the greatest capital investment. A review of these proposals revealed that Proposal 1 offered coarse solids separation and regrind facilities to reduce the maximum particle size that would be transferred by the pipeline. Proposal 2 provided solids dewatering facilities prior to rail haul to the disposal site. The capital costs of these dewatering, regrinding, and transport facilities were included in the Silver Bay treatment plant and contributed to their high initial capital cost.

## Tailings Transport Systems

### Pipeline

Overland piping of a tailings slurry was specified in nine of the twenty proposals for transport of the tailings to a final disposal site. Six of these proposals were developed by Bechtel Corporation and were identical. Of the remaining three, two were developed by Trygve Hoff and Associates, while the last was prepared by Parsons-Jurden Corporation. The Parsons-Jurden Proposal (No. 13) called for a pipeline to transport tailings to its proposed lake shore impoundment. Because this pipeline would cover a relatively short distance and would not be utilized for long-distance overland transportation, it is difficult to compare No. 13 with the other eight proposals involving overland piping.

Table 4 offers a comparison between the overland pipelines proposed by Bechtel Corporation and by Trygve Hoff and Associates. More importantly, however, it reveals the basic design parameters of each pipeline, indicating why the pipelines differ so greatly.

Table 4

Comparison of Pipeline Schemes and Design Parameters
(Proposed by Reserve Mining Task Force)

| | Proposal 1 (Trygve Hoff) | Proposal 3 (Trygve Hoff) | Proposals 6 through 11 Bechtel |
|---|---|---|---|
| Pipeline | | | |
| Number of Lines | 7[1] | 2 | 2 |
| Diameter, inches | 16 | 14 | 14 |
| Length, feet | 33,500 | 33,500 | 19,500 |
| Pump Stations | 10 | 10 | 1 |
| Design Parameters | | | |
| Size of Tailings | <8 mesh | <500 mesh | <35 mesh |
| Solids, percent | 30 | 40 | 50 |
| Solids, Long Tons/Day | 65,000 | 15,000 | 34,500 |
| Operating Pressure, psi | N.A.[2] | 425 | 850 |

[1] Includes 2 standby lines.
[2] Information Not Available.

Proposal 1 concerned the pumping of both coarse and fine tailings to the disposal area. The quantity of tailings to be transported and the quantity of water required to carry the solids resulted in the proposal of five separate pipelines, two standby lines, and ten separate lift stations. Proposal 3 provided for the pumping of only the fine fraction of the tailings. Less water would be required to transport the fines, which could be pumped as a slurry with higher solids concentrations, and only two 14-inch diameter pipelines would be required to transport the tailings. Ten pump stations would also be required in this proposal, to lift the tailings to the disposal area.

Proposals 6 through 11 were similar to Proposal 3 in that only fine tailings would be transported by the pipeline. In these six proposals, certain design differences were able to effect significant cost reduction. These differences included the selection of a shorter route to the disposal area, a decreased water requirement to carry the solids by using a 50-percent slurry, and the use of only one pumping station, with high-lift and high-pressure capabilities.

Comparison of these piping alternatives reveals substantial cost savings in the facilities presented in Proposals 6 through 11. The cost information presented in Table 5 reveals that the pipeline included in Bechtel's six approaches represents a $5.2 million (approximately) cost reduction from Proposal 3 and a $29 million cost saving from Proposal 1. Note should be made, however, that substantial cost savings in one transport method in one part of the system may result in equally substantial cost increases to another method in some other part of the system. For this reason, a comparison of the total transport systems is made at the end of this section.

### Conveyor

Only Proposals 8 and 9 (prepared by Bechtel Corporation) investigated the utilization of an overland conveyor to transport tailings to the impoundment area selected (Lower Lax Lake area). The conveyor would transport only coarse tailings (+35 mesh) as they discharge from the proposed spiral classifier. The 18,000-ft. conveyor would be enclosed, and insulation would be provided for full-year operation. Half-year operations, although not requiring insulation, would require twice the capacity to move an entire year's tailings. The full-year operation would cost approximately $2 million less than the half year operation.

### Railroad

Rail haul of tailings to an on-land disposal site was investigated in Proposals 2, 6, 7, 10, and 11. Of these five proposals, Nos. 2, 6, and 10 were concerned with year-round operation, while Nos. 7 and 11 developed the rail haul requirements for a half-year operation during the summer months.

The possibility of hauling all the tailings to a disposal site near the mine at Babbitt was investigated by Proposal 2. This was the only proposal that investigated the requirements to haul all the tailings by rail. Tailings were to be contained in solid-bottom gondola cars without the addition of insulation or heating elements. Thawing sheds were recommended, however, to assist in the dumping of cars during freezing weather. Hauling would be done in two stages, with the first stage occurring at Mile 21. Three 112-car trainloads of tailings would be hauled to this point for every train of 120 empty cars. From this point, three trains with 112 loaded cars and 40 empty cars would proceed

## Table 5

Capital Cost-Breakdown of 19 Disposal Proposals Prepared for
Reserve Mining Company

| Proposal No. | In-Plant Alterations | On-Site Processing | Tailings Transport System |  |  |  | Final Disposal |  |  | Additional Cost Required | Estimated Capital Cost[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Pipeline | Conveyor | Railroad | Gravity Discharge | Lake Superior | Lax Lake | Other |  |  |
| 1 |  | $26,799,000 | $34,147,000 |  |  |  |  | $69,126,000[2] |  | $21,011,000 | $151,083,000 |
| 2 |  | 28,072,000 |  |  | $24,137,000 |  |  |  | $10,949,000 | 10,974,000 | 74,132,000 |
| 3 |  | 10,945,000 | 9,921,000 |  |  |  | N.A. | 6,284,000[2] |  | 5,573,000 | 32,726,000 |
| 4 |  | 11,612,000 |  |  |  | N.A. | N.A. |  |  | 3,242,000 | 14,854,000 |
| 5 |  |  |  |  |  | $528,000 | $2,593,200 |  |  | 467,000 | 3,584,000 |
| 6 | $3,400,000 | 5,600,000 | 4,700,000 |  | 6,000,000 |  |  | 18,800,000[2] |  | 4,000,000 | 44,100,000 |
| 7 | 3,400,000 | 5,800,000 | 4,700,000 |  | 11,000,000 |  |  | 18,400,000[2] |  | 4,500,000 | 49,400,000 |
| 8 | 3,400,000 | 5,600,000 | 4,700,000 | 14,000,000 |  |  |  | 16,300,000 |  | 4,400,000 | 48,200,000 |
| 9 | 3,400,000 | 5,800,000 | 4,700,000 | 16,200,000 |  |  |  | 17,100,000 |  | 4,700,000 | 51,200,000 |
| 10 | 3,400,000 | 5,600,000 | 4,700,000 |  | 12,100,000 |  |  | 16,200,000 | —[2] | 4,200,000 | 46,200,000 |
| 11 | 3,400,000 | 5,800,000 | 4,700,000 |  | 19,100,000 |  |  | 16,400,000 | —[2] | 4,900,000 | 54,300,000 |
| 12 |  |  |  |  |  | No Cost Breakdown Available |  |  |  |  | Incomplete |
| 13 |  |  |  |  |  | No Cost Breakdown Available |  |  |  |  | 27,449,000 |
| 14 |  |  |  |  |  | No Cost Breakdown Available |  |  |  |  | 11,620,000 |
| 15 |  |  |  |  |  | No Cost Breakdown Available |  |  |  |  | 13,066,000 |
| 16 |  |  |  |  |  | No Cost Breakdown Available |  |  |  |  | N.A. |
| 17 | 19,738,000 |  |  |  |  |  |  |  |  | 1,184,000 | 39,910,000[3] |
| 18 |  |  |  |  |  | No Cost Breakdown Available |  |  |  |  | N.A. |
| 19 |  | 1,625,000[4] |  |  |  |  |  |  |  | 325,000 | 1,900,000[5] |
| 20 |  |  |  |  |  | No Cost Breakdown Available |  |  |  |  | 14,000,000 |

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[1] Capital costs include equipment, construction, design and supervision costs.

[2] Cost requirements for Disposal Site 7 are included in costs for Lax Lake. A further cost breakdown was not available from the information provided.

[3] Capital Cost for Dry Cobbing as part of each line of concentrating equipment. Capital Cost for Dry Cobbing between crushing and concentrating steps is estimated at $34,013,000.

[4] Proposal No. 19 concerns processing facilities specifically for preparation of tailings for marketing sand and aggregate materials.

[5] Capital investment = Cost of Construction + Working Capital + Preoperational Charge + Startup.

to Babbitt. With this scheduling, the tailings could be hauled to the Babbitt disposal area, and the ore cars could be returned to the mine for another load of taconite.

Proposals 6 and 7 provided for the rail haul of coarse tailings to the Lower Lax Lake Area for disposal. These proposals were for full-year and half-year operations, respectively. Bottom-dump hopper cars with insulation and heating were recommended for fast unloading. One 60-car train would be required for full-year operation, while two trains would be needed for the half-year operation. The railroad requirements for Proposals 6 and 7 were based on annual coarse tailings of 15 million tons, while Proposal 2 was developed for a peak of 36 million tons annually.

Proposals 10 and 11 investigated the possibility of hauling the coarse tailings (+35 mesh) to a disposal site located at Mile 32 of the existing railroad. These proposals were also full-year and half-year operations, respectively. Solid-bottom cars were selected to carry the tailings to the disposal site because of the lower capital cost. The greater haul distance involved did not provide the bottom dump cars (as used in Proposals 6 and 7) with enough of a time advantage to justify the expenditure. Insulation and heaters would be provided for each of the cars, with a thawing shed located at the disposal point for emergencies. The railroad requirements were based upon annual production of 15 million tons of coarse tailings (+35 mesh).

Economic comparisons reveal that Proposal 2, which required the transportation of the greatest amount of tailings over the greatest distance, required the largest capital investment. Proposals 10 and 11, which required a shorter haul distance for disposal of only the coarse tailings (+35 mesh), realized an appreciable cost savings over Proposal 2. Proposals 6 and 7 have a lower cost because of a still shorter haul distance and the quick turn-around time provided by the bottom-dump hopper cars which were recommended. Cost reductions of $6 to $8 million would be achieved in comparison to Proposals 10 and 11, respectively, and $13 to $18 million in comparison to Proposal 2.

### Gravity Discharge

Seven of the twenty proposals provided gravity discharge as a method of transporting the tailings. In all cases, this method would provide for the discharge of tailings directly to Lake Superior. The only basic difference among most of these proposals was the depth at which the tailings would enter the Lake. In four of these proposals, a separation would be made between fine tailings and coarse tailings. Fine tailings would then be discharged at depths varying from 150 feet to 300 feet, while coarse tailings would either be discharged to the existing tailings delta or to the Lake at depths as great as 150 feet. In Proposal 5, all tailings would be discharged behind an impervious curtain anchored in Lake Superior. The curtain would extend to a depth of 100 feet and therefore prevent tailings from entering the open part of the lake in the top 100 feet.

The final two proposals which recommended gravity discharge of the tailings included a plan for discharging all the tailings to the Lake using a submerged discharge. Tailings would not be separated into coarse and fine fractions, but rather would be thickened and discharged at depths of 150 feet or greater through several diffuser pipes. The release of tailings would then create a heavy density current, which would seek the lake bottom. This approach represents Reserve Mining's current plan to modify the tailings discharge system, which is identified as Proposal 20, and is also similar to the approach used in Proposal 15.

Capital cost requirements concerning the gravity discharge of tailings to Lake Superior were not presented in enough detail to provide an economic comparison with other proposals. Only Proposal 5 offered a separate capital cost ($528,000) for the construction of gravity discharge facilities.

### Total Tailings Transport Comparisons

A review of the transport systems offered by all of the comparable approaches has revealed that the selected final disposal method is the dominant influence on the capital cost of transportation. In-lake disposal offered the least-cost approach, while total on-land disposal at Babbitt provided the most expensive. Separation of the tailings into coarse and fine fractions, with separate transport systems, offered cost savings over the other on-land disposal proposals.

In general, review of these approaches indicates that the overland piping of fines to the Lax Lake area combined with the rail haul of coarse tailings to the same area offered the least-cost transport system for the total on-land disposal of tailings. The use of overland conveyors to transport coarse tailings to the Lax Lake area generally proved more expensive than rail haul.

## Final Disposal

The final disposal of tailings has been divided into two major approaches which are either "In-Lake" disposal or "On-Land" disposal. "In-Lake" disposal concerns the complete or partial discharge of tailings directly to Lake Superior, while "On-Land" disposal refers to the transportation of tailings to an on-land impoundment area. The prime on-land disposal areas of concern are: the Lower Lax Lake area; the site at Mile Post 32 of the Reserve Mining Railroad; and a disposal site near the mine at Babbitt.

### Lake Superior

This largest of the Great Lakes was offered as a disposal point in eight of the twenty proposals that were developed. Essentially no preparation of the receiving lake area is required, since tailings are released to the Lake and are allowed to seek the lake bottom via gravity settling. Transportation of the tailings to the Lake bottom is by means of the "heavy density current" that is reported to be developed by the discharge of the tailings. Discharge configurations, which have been discussed in the Tailings Transport Systems section, constitute the only method offered for controlling the tailings discharge to the Lake.

In all but one case, there was no capital investment required for site preparation for in-lake disposal. The one exception was Proposal 5, which suggested the construction of an impervious curtain within the lake. This curtain would contain the tailings to a depth of approximately 100 feet, where they would pass underneath the curtain into the open water of the lake. The estimated cost of this curtain (which would implement a theory that has no existing practical application) was approximately $2,593,000.

### Lax Lake Area

Because of its size and proximity to the Silver Bay Plant, the Lax Lake Area was selected by eight of the twenty proposals as the final disposal point for all or part of the tailings.

The area of concern includes the marsh-like valley, which lies approximately southwest of the Lake. In some cases, the disposal area has been extended to include Lax Lake itself.

The use of this area as an impoundment basin required that all the proposals investigate several common problems. These problems were: the construction of dams to contain the tailings; the diversion of surface runoff from the impoundment; and the final condition of the disposal site.

All the proposals recommended earthen-type dams for containing the tailings. Proposals 1 and 3 suggested totally rock-filled dams, while Proposals 6 through 11 suggested the possibility of using the coarse tailings for dam construction. A rock toe would be utilized in Proposals 6 through 11 to stabilize the downstream base of the dam and tailings would be used to construct the remaining portion of the dam.

Proposals 1 and 3 also provide for a concrete facing on the impoundment side of the dam to prevent liquid flow through the dam while Proposals 6 through 11 suggest a compacted glacial till.

Proposals 1 and 3 recommend the construction of a drainage ditch north of the basin to divert runoff around the embankments. This ditch would prevent the rainfall runoff from a collection area of approximately 40 square miles from entering the basin. Proposals 6 through 11, however, did not recommend large-scale runoff diversion. Initial design assumptions were that the basin volume would be large enough to contain a one-year runoff without overtopping the dams. For this reason, low-level outlet structures were designed to permit the release of the stored water within one year.

The basic technical differences discussed above define the basis for the disposal site cost differences that exist between the proposals developing the Lax Lake area as an impoundment area. Construction of dams is the major cost item with the required volume of the basin being the major factor influencing this cost. The smaller volume of fine tailings offered in the Bechtel proposals, coupled with their recommendation to use coarse tailings for dam construction, produced a $50 million cost saving over Proposal 1.

The large impoundment basin cost difference between the Bechtel proposals and Proposal 3 can be attributed to the cost of coarse tailings conveyors and stackers. This equipment was required in the Bechtel proposals to carry the coarse tailings to the dam construction site. Approximately $10 million would be required for this equipment, and would not be necessary for Proposal 3.

### Other Areas

Two additional disposal areas were considered. Site No. 7 from Bechtel's Proposals 10 and 11, located at Mile 32 of the Reserve Mining Railroad is recommended as a possible depository for tailings. The other site is located near Reserve's Babbitt Mine. This second site was developed in Proposal 2 and offers a five-year capacity for the deposit of all Concentrator Plant Tailings.

Both of these tailings disposal sites offer the advantage of elimination of a requirement for extensive dam construction. The tailings would be hauled to these sites by rail, thus necessitating the removal of all excess water before the tailings are loaded on the cars. The major cost requirements for these alternatives would be for unloading facilities and tailings conveyor equipment. Proposals 10 and 11 (Bechtel) would require approximately $5 million of additional capital investment over the disposal site costs for Proposal 2. The additional equipment required for dam construction at the Lax Lake site was included in the Bechtel disposal site costs and contributed to this large difference. Unfortunately, a detailed breakdown was not available to separate the Lax Lake disposal cost requirements from the Site No. 7 requirements, and further economic comparisons of Proposal 2 with Proposals 10 and 11 are not possible.

## General Comments on Previous Tailings Disposal Alternatives

The various proposals reviewed in this Section appear to be products of preliminary engineering studies and as such do not reflect, in most cases, the detail that would be required for a final design. For this reason, significant differences may exist between the various proposals because of differences in basic design assumptions or the method of approach. This review attempted to compare only similar operations within these alternatives, and did not attempt to judge the validity of each alternative. It must be assumed that because the basis of design and the preliminary design assumptions for each alternative have been presented in their respective reports, each alternative offers a valid attempt at solving the tailings discharge problem

It should be mentioned that no evidence of deliberate over-engineering or over-estimating has been detected. It is evident, however, that some alternatives are more conservative than others and therefore produce differences in equipment and capital requirements. These conservative alternatives are justified by the constraints of their basis of design or preliminary design assumptions, and should not be construed as over-engineered or over-estimated.

This review of the previous proposals has allowed a greater insight into various methods of handling, processing and disposal of the tailings. It has also influenced this investigation consistent with the philosophy of obtaining a minimum-cost solution for the industry, while complying with the objectives of the Enforcement Conference.

## SECTION IV

## PROCESS INVESTIGATION

### General Approach

Wastewater sampling and analyses and treatability studies were conducted by ROY F. WESTON personnel at the plant site and at the ROY F. WESTON laboratories to determine the treatment efficiency of potential processes for treating the tailing wastes generated at Reserve Mining's Silver Bay taconite beneficiation facilities. Sampling and treatability studies were conducted at the plant from June 10, 1971 to June 22, 1971 and continued at the ROY F. WESTON laboratories until July 5, 1971. The five-phase sampling and testing program included the following:

1. Process water sampling on a representative process operation (Concentrator Line No. 105), the two Effluent Launders, and the Pelletizer-Thickener overflow and the raw intake water.
2. Preliminary flocculant testing.
3. Settling rate tests on various wastewater samples.
4. Eight-foot column settling studies for performance parameters of selected polyelectrolytes.
5. Thickening and dewatering studies, including vacuum filtration and centrifugation tests.

### Summary of Wastewater Characteristics

Wastewater generated at Reserve Mining's ore beneficiation plant is discharged to Lake Superior through two effluent launders. Each launder serves approximately one-half of the production facilities. In the effluent sampling programs, it was decided to sample both effluent launders. Sampling of process water was restricted to one process line in-plant (selected as typical of the overall processing operation), because sampling of each production line was impractical. In discussions with Reserve Mining, the Company indicated that Concentrator Line No. 105 was most representative of their production, and, therefore, this line was used in all in-plant sampling work. Additional wastewater samples were collected from the Pelletizer-Thickener overflow and from the raw water intake.

The samples collected from both the East and the West Launders were obtained just outside the beneficiation process building. The East Launder was sampled approximately 25 feet upstream from the point at which additional dilution water is added. Wastewater samples were collected near the surface of these two launders and are not representative of the wastewater characteristics of the total flow in the launders. Since the coarse tailings settle toward the bottom of the launders and also tend to move in "slugs" downward through the launder, it is impossible to obtain a truly representative sample of wastewater from these launders. However, the intent in sampling the launder process waters was not necessarily to obtain a truly representative sample of the overall effluent solids, but rather to sample the finer portion of the solids in the process water.

In-plant samples were taken from Concentrator Line No. 105 from two sides of the various concentrating units. The units sampled were the Cobber, Magnetic Rougher, Siphon Sizer the Magnetic Finisher, and the Hydroseparator overflow.

The ROY F. WESTON Project Scientist, working with personnel from Reserve Mining, undertook to collect one grab sample each hour (between 8 a.m and 12 noon on 16 June 1971) from each of these sampling locations and to combine them into a four-hour composite sample. Although they are not included in the report, photographs were taken by Reserve Mining Company of the five sampling locations on Line No. 105, as well as the sampling locations on the East and West Launders; these photographs will remain in the project files for future reference. Sufficient wastewater was collected at each location to composite three one-gallon samples. One composite sample was left "as is", while the other two samples were filtered by Reserve personnel on their equipment. One of the two samples was filtered through a 0.45-micron Millipore Filter and the other through a 0.1-micron Millipore Filter. Duplicate and sequential samples were collected at the same time and filtered in the same manner and left at Reserve Mining Company for analysis. The two filtered samples shipped to the ROY F. WESTON laboratory for analysis each had a 500-ml portion acidified with nitric acid by Reserve personnel as a preservative for future analysis of chromium and chloride content. The remaining portions of the two filtered samples were acidified with concentrated hydrochloric acid by Reserve personnel to prevent degradation. The "as is" sample was not preserved.

The analytical results of these samples as determined in the ROY F. WESTON laboratories are shown in Table 6. The COD and total dissolved solids analytical results on the filtered samples were felt to be erroneous and therefore are not reported. All of the filtered samples had been preserved by the addition of hydrochloric acid, which would increase the total dissolved solids to some higher than actual value. Since the COD results of all of the preserved samples were significantly higher than the unpreserved samples, it was felt that the preservative possibly was contaminated with organics, causing high and erroneous results. These results were not reported.

Sequential samples collected at the same locations were prepared in a manner similiar to the samples shipped to the ROY F. WESTON laboratories, except that they were not preserved. These unpreserved samples were analyzed by Reserve personnel. The results of analysis of these samples given to ROY F. WESTON personnel by Reserve on 17 August 1971, are compared in Table 7 to the results of comparable samples analyzed by ROY F. WESTON.

Table 6

Summary of Results of Analysis of Preserved
Filtered and Unfiltered Process Water Samples

| Weston Sample No. | Sample Description | | COD mg/l | TDS mg/l | pH | Alkalinity mg/l | Acidity mg/l | Cl mg/l | $SO_4$ mg/l | F mg/l | Mn ppb[1] | Ca mg/l | Cu ppb[1] | Zinc ppb[1] | Cr mg/l | Se[3] mg/l | Hg ppb[1] | As mg/l | Fe ppb[1] | Mg mg/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **East Launder** | | | | | | | | | | | | | | | | | | | |
| 2474 | No. 73 | Unfiltered | 24 | 90 | 7.5 | 94 | 8 | | | | 5,700[2] | 25.0 | <50[2] | 80[2] | <0.05 | <2 | <0.2 | <0.5 | 96,000[2] | 17.2 |
| 2475 | No. 74 | Filtered - 0.45μ | | | | | | 4.16 | <1 | 0.64 | 5.0 | 12.5 | 3.6 | <2 | <0.05 | <2 | 0.25 | <0.5 | 16.0 | 3.5 |
| 2476 | No. 74A | Filtered - 0.1μ | | | | | | | <1 | 0.08 | 15.4 | 12.5 | 2.6 | 6.3 | | <2 | <0.2 | <0.5 | <1.0 | 3.5 |
| | **West Launder** | | | | | | | | | | | | | | | | | | | |
| 2477 | No. 75 | Unfiltered | 16 | 87 | 8.1 | 92 | 2 | | | | 47,000[2] | 47.0 | 420[2] | 350[2] | 0.08 | <2 | 0.25 | <0.5 | 330,000[2] | 33.8 |
| 2478 | No. 76 | Filtered - 0.45μ | | | | | | 3.78 | 2.4 | 0.25 | 2.5 | 12.8 | 2.0 | <2 | <0.05 | <2 | <0.2 | <0.5 | 10 | 3.5 |
| 2479 | No. 76A | Filtered - 0.1μ | | | | | | | <1 | 0.15 | <2.0 | 13.2 | 4.9 | 7.2 | | <2 | <0.2 | <0.5 | 10.1 | 3.5 |
| | **Cobber Tailings** | | | | | | | | | | | | | | | | | | | |
| 2480 | No. 77 | Unfiltered | 24 | 112 | 8.6 | 366 | | | | | 24,000[2] | 58.4 | 500[2] | 570[2] | 0.28 | <2 | <0.2 | <0.5 | 980,000 | 122 |
| 2481 | No. 78 | Filtered - 0.45μ | | | | | | 3.97 | <1 | 0.66 | <2.0 | 11.0 | 3.6 | <2 | <0.05 | <2 | <0.2 | <0.5 | 5.0 | 4.5 |
| 2482 | No. 78A | Filtered - 0.1μ | | | | | | | <1 | 0.25 | 5.0 | 11.0 | 3.1 | 2.2 | | <2 | 0.2 | <0.5 | <1.0 | 4.4 |
| | **Rougher Tailings** | | | | | | | | | | | | | | | | | | | |
| 2483 | No. 79 | Unfiltered | 16 | 78 | 8.4 | 112 | | | | | 8,000[2] | 49.5 | 360[2] | 370[2] | <0.05 | <2 | 0.2 | <0.5 | 350,000 | 49.6 |
| 2484 | No. 80 | Filtered - 0.45μ | | | | | | 3.97 | <1 | 0.24 | 5.1 | 11.0 | 3.5 | <2 | <0.05 | <2 | <0.2 | <0.5 | 38 | 4.1 |
| 2485 | No. 80A | Filtered - 0.1μ | | | | | | | <1 | 0.16 | 2.5 | 10.6 | 5.8 | <2 | | <2 | 1.65 | <0.5 | 6 | 4.0 |
| | **Siphonsizer Overflow** | | | | | | | | | | | | | | | | | | | |
| 2486 | No. 81 | Unfiltered | 16 | 81 | 8.3 | 68 | | | | | 5,800[2] | 40.0 | 340[2] | 330[2] | 0.1 | <2 | <0.2 | <0.5 | 250,000[2] | 32.8 |
| 2487 | No. 82 | Filtered - 0.45μ | | | | | | 3.97 | <1 | <0.1 | <2.0 | 11.1 | 8.4 | 2.5 | <0.05 | <2 | 1.25 | <0.5 | 26 | 3.8 |
| 2488 | No. 82A | Filtered - 0.1μ | | | | | | | <1 | 0.14 | 3.0 | 11.1 | 6.8 | 23.7 | | <2 | 0.45 | <0.5 | 22 | 3.7 |
| | **Finisher Tailings** | | | | | | | | | | | | | | | | | | | |
| 2489 | No. 83 | Unfiltered | 36 | 100 | 8.0 | 68 | 1 | | | | 5,000[2] | 33.5 | 300[2] | 410[2] | <0.05 | <2 | <0.2 | <0.5 | 290,000[2] | 25.7 |
| 2490 | No. 84 | Filtered - 0.45μ | | | | | | 2.65 | <1 | 0.32 | 7.3 | 13.1 | 2 | <2 | <0.05 | <2 | <0.2 | <0.5 | 20 | 3.3 |
| 2491 | No. 84A | Filtered - 0.1μ | | | | | | | <1 | <0.1 | 7.3 | 12.8 | 3 | 2.2 | | <2 | <0.2 | <0.5 | 9 | 3.1 |
| | **Hydroseparator Overflow** | | | | | | | | | | | | | | | | | | | |
| 2492 | No. 85 | Unfiltered | 24 | 62 | 7.8 | 54 | 2 | | | | 630[2] | 15.7 | 420[2] | 260[2] | 0.1 | <2 | <0.2 | <0.5 | 60,000[2] | 5.5 |
| 2493 | No. 86 | Filtered - 0.45μ | | | | | | 3.40 | <1 | <0.1 | 17.6 | 13.4 | 2.4 | <2 | <0.05 | <2 | <0.2 | <0.5 | 33 | 3.0 |
| 2494 | No. 86A | Filtered - 0.1μ | | | | | | | <1 | 0.18 | 11.5 | 13.2 | 3.1 | 2.7 | | <2 | <0.2 | <0.5 | <1 | 2.8 |
| | **Pelletizer-Thickener Overflow** | | | | | | | | | | | | | | | | | | | |
| 2495 | No. 87 | Unfiltered | 24 | 90 | 7.3 | 46 | 4 | | | | 400[2] | 8.0 | 240[2] | 260[2] | 0.1 | <2 | <0.2 | <0.5 | 77,000 | 7.2 |
| 2496 | No. 88 | Filtered - 0.45μ | | | | | | 3.78 | 6.4 | 0.62 | 11.0 | 12.2 | 5.0 | 2.2 | <0.05 | <2 | 2.95 | <0.5 | 12 | 2.7 |
| 2497 | No. 88A | Filtered - 0.1μ | | | | | | | 5.2 | 0.57 | 11.3 | 12.1 | 3.3 | 3.7 | | <2 | <0.2 | <0.5 | <1 | 2.6 |
| | **Water Intake** | | | | | | | | | | | | | | | | | | | |
| 2498 | No. 89 | Unfiltered | 12 | 82 | 7.2 | 50 | 8 | | | | 2.2 | 7.5 | 4.9 | 5.1 | 0.08 | <2 | 0.8 | <0.5 | 22 | 2.3 |
| 2499 | No. 90 | Filtered - 0.45μ | | | | | | 3.40 | 3.6 | <0.1 | <2.0 | 13.2 | 3.3 | 4.5 | <0.05 | <2 | 2.05 | <0.5 | 19 | 2.4 |
| 2500 | No. 90A | Filtered - 0.1μ | | | | | | | 2.4 | 0.12 | 13.0 | 13.2 | 3.9 | 6.7 | | <2 | <0.2 | <0.5 | 28 | 2.4 |

[1] Metals analysis in the ppb range were performed by organic extraction using MIBK.
[2] Contaminant measured in the mg/l concentration range and converted to ppb by multiplying concentration by 1000.
[3] Selenium analysis performed using new lamp, however, sensitivity was only good to 2.0 mg/l

## Table 7

Comparison of Analytical Results of Samples
Collected June 16, 1971

| | Analyzed By | Millipore Filter Size microns | Plant Intake | East Launder | West Launder | Cobber Tails | Rougher Tails | Siphon Sizer Tails | Finisher Tails | Hydro-Separator Tails | Pelletizer Overflow |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Calcium** | Reserve | 0.45 | 12.6 | 12.3 | 12.1 | 10.6 | 10.3 | 10.9 | 12.3 | 12.9 | 11.6 |
| | Weston | 0.45 | 13.2 | 12.5 | 12.8 | 11.0 | 11.0 | 11.1 | 13.1 | 13.4 | 12.2 |
| **Magnesium** | Reserve | 0.45 | 2.8 | 3.6 | 3.6 | 4.6 | 4.2 | 4.0 | 3.4 | 3.1 | 2.9 |
| | Weston | 0.45 | 2.4 | 3.5 | 3.5 | 4.5 | 4.1 | 3.8 | 3.3 | 3.0 | 2.7 |
| **Sulfate** | Reserve | 0.45 | 2.9 | 3.6 | 3.7 | 4.3 | 5.2 | 3.8 | 3.6 | 3.6 | 7.1 |
| | Weston | 0.45 | 3.6 | <1.0 | 2.4 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | 6.4 |
| **Chloride** | Reserve | 0.45 | 1.4 | 2.6 | 2.7 | 4.1 | 3.6 | 1.6* | 1.4 | 2.0 | 1.6 |
| | Weston | 0.45 | 3.4 | 4.16 | 3.78 | 3.97 | 3.97 | 3.97 | 2.65 | 3.4 | 3.78 |
| **Fluoride** | Reserve | 0.45 | 0.05 | 0.07 | 0.09 | 0.10 | 0.10 | 0.09 | 0.06 | 0.05 | 0.50 |
| | Weston | 0.45 | <0.1 | 0.64 | 0.25 | 0.66 | 0.24 | <0.1 | 0.32 | <0.1 | 0.62 |
| **Iron** | Reserve | 0.45 | 0.014 | 0.022 | 0.014 | 0.020 | 0.032 | 0.066 | 0.036 | 0.093 | 0.013 |
| | Reserve | 0.10 | 0.009 | 0.002 | 0.003 | 0.003 | 0.003 | 0.003 | 0.004 | 0.025 | 0.003 |
| | Weston | 0.45 | 0.019 | 0.016 | 0.010 | 0.005 | 0.038 | 0.026 | 0.020 | 0.033 | 0.012 |
| | Weston | 0.10 | 0.028 | <0.001 | 0.0101 | <0.001 | 0.006 | 0.022 | 0.009 | <0.001 | <0.001 |
| **Manganese** | Reserve | 0.45 | <0.001 | 0.039 | 0.034 | 0.032 | 0.016 | 0.020 | 0.025 | 0.081 | 0.030 |
| | Reserve | 0.10 | <0.001 | 0.033 | 0.037 | 0.029 | 0.018 | 0.020 | 0.020 | 0.027 | 0.035 |
| | Weston | 0.45 | <0.002 | 0.005 | 0.0025 | <0.002 | 0.0051 | <0.002 | 0.0073 | 0.0176 | 0.0110 |
| | Weston | 0.10 | 0.013 | 0.0151 | <0.002 | 0.005 | 0.0025 | 0.003 | 0.0073 | 0.0115 | 0.0113 |
| **Copper** | Reserve | 0.45 | 0.0012 | 0.0004 | 0.0007 | 0.0004 | 0.0009 | 0.0007 | 0.0007 | 0.0011 | 0.0024 |
| | Reserve | 0.10 | 0.0011 | 0.0005 | 0.0007 | 0.0006 | 0.0005 | 0.0007 | 0.0013 | 0.0015 | 0.0014 |
| | Weston | 0.45 | 0.0033 | 0.0036 | 0.0020 | 0.0036 | 0.0035 | 0.0084 | 0.0020 | 0.0024 | 0.0050 |
| | Weston | 0.10 | 0.0039 | 0.0026 | 0.0049 | 0.0031 | 0.0058 | 0.0068 | 0.0030 | 0.0031 | 0.0033 |
| **Zinc** | Reserve | 0.45 | 0.0017 | 0.0006 | <0.0005 | 0.0006 | 0.0006 | <0.0005 | <0.0005 | <0.0005 | 0.0046 |
| | Reserve | 0.10 | 0.0014 | 0.0010 | <0.0005 | <0.0005 | <0.0005 | 0.0006 | <0.0005 | 0.0020 | 0.0021 |
| | Weston | 0.45 | 0.0045 | <0.0020 | <0.0020 | <0.0020 | <0.0020 | 0.0025 | <0.0020 | <0.0020 | 0.0022 |
| | Weston | 0.10 | 0.0067 | 0.0063 | 0.0072 | 0.0022 | <0.0020 | 0.0237 | 0.0022 | 0.0027 | 0.0037 |
| **Chromium** | Reserve | 0.45 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| | Weston | 0.45 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| **pH** | Reserve | | 8.0 | 8.5 | 8.5 | 8.8 | 8.6 | 8.5 | 8.5 | 8.3 | 8.1 |
| | Weston | | 7.2 | 7.5 | 8.1 | 8.6 | 8.4 | 8.3 | 8.0 | 7.8 | 7.3 |

**NOTE:** All results except pH in mg/l.

Subsequently, ROY F. WESTON personnel requested Reserve to collect, filter, and freeze (instead of preserving) additional samples for COD and total dissolved solids analysis. The results of ROY F. WESTON analyses on these new samples are shown in Table 8. Reserve also analyzed these samples both before freezing (immediately after collection) and after the samples had thawed. The results of their analyses, as transmitted to ROY F. WESTON on 13 September 1971, are shown in Table 9.

Table 8

Results of COD and Total Dissolved Solids Analyses of Unpreserved Samples[1]

| | COD mg/l | Total Dissolved Solids mg/l |
|---|---|---|
| Plant Intake Water | | |
| As Collected | 6.3 | ------ |
| 0.45μ Filtered | 2.3 | 48[2] |
| West Launder | | |
| As Collected | 45 | ------ |
| 0.45μ Filtered | 2.9 | 58[2] |
| East Launder | | |
| As Collected | 24.4 | ------ |
| 0.45μ Filtered | 2.3 | 62[2] |

[1] Analytical work performed by ROY F. WESTON.
[2] Average of three determinations.

Table 9

Comparison of COD and Total Dissolved Solids Analyses on Samples Before Freezing and After Thawing[1]

| | Before Freezing | | After Thawing | |
|---|---|---|---|---|
| | COD mg/l | T.D.S. mg/l | COD mg/l | T.D.S. mg/l |
| Plant Intake Water | | | | |
| Unfiltered | 1.8 | 51.4 | 4.8[2] | 52.0 |
| Filtered, 0.45 micron | <1.6 | 53.8 | 6.7[2] | 55.1 |
| West Launder | | | | |
| Unfiltered | 38.5 | 55.7 | 57.5 | 55.7 |
| Filtered, 0.45 micron | 4.8 | 55.7 | 10.4 | 55.7 |
| East Launder | | | | |
| Unfiltered | 25.6 | 52.6 | 36.5 | 56.6 |
| Filtered, 0.45 micron | 1.6 | 56.3 | 4.2 | 57.2 |

[1] Analytical work performed by Reserve Mining Company.
[2] Average of two determinations.

Samples of wastewater tailings were collected by ROY F. WESTON and Reserve Mining personnel from both the Cobber and the Rougher, and were filtered through 100-mesh screening. Fifty pounds of tailings from the Cobber and 25 pounds of tailings from the Rougher remaining on the 100 mesh screen were collected and dried. These tailings were then shipped to the ROY F. WESTON laboratories for subsequent evaluation of the utilization of tailings in the manufacture of bricks. The results of these investigations are discussed in the section on 'Tailings Utilization and Recovery'.

## Investigative Program and Results

### Preliminary Flocculant Testing

Tests to determine flocculant performance on this wastewater, with inorganic chemicals and with organic polyelectrolytes (polymers), were conducted by ROY F. WESTON personnel. The wastewater used in the evaluation was collected from the surface of the East Launders. A three-gallon bucket was dipped into the flow in this launder and retrieved after filling. The sole purpose of sampling the launder was to obtain tailings that could be separated into a sample containing tailings less than 100-mesh in size. This sieve size was arbitrarily selected because it was felt that the 100-mesh point of separation could be obtained with field equipment and also this point of separation could be adjusted upwards or downwards without affecting the results of the tests. The collected wastewater was filtered through a 100-mesh sieve, with the larger material being discarded and the wastewater passing this sieve being used in the preliminary flocculant studies.

The flocculant test was conducted using a standard Phipps-Bird stirring apparatus. One-liter samples were treated with the desired dose of chemical and then mixed, flocculated, and allowed to settle. The standard procedure included mixing for one minute at 100 rpm stirring an additional five minutes at 15 rpm and then allowing the sample to settle for 15 minutes before comparing the samples. This standard procedure was modified shortly after beginning the studies by allowing the samples to be flocculated (stirred) for five minutes at 75 rpm as compared to 15 rpm in the initial procedure. This modified procedure is noted on the raw data, and it generally produced a better supernatant quality after settling. However, the optimum results for mixing and flocculation detention time and for energy requirements should be determined from the results of pilot-plant tests.

The raw data collected from the inorganic flocculant tests are shown in Table 10, and the raw data from the preliminary organic polyelectrolyte tests are shown in Table 11. The inorganic chemicals used in the flocculant studies were lime, ferric chloride, and alum The most effective organic polyelectrolytes were the cationic polyelectrolytes: Dow PEI 600, Nalco 603, and Calgon M-500. Anionic and non-ionic polyelectrolytes were tried and found to be ineffective. In addition, mixtures of cationic and anionic polyelectrolytes were tried in order to determine if a reduced treatment dosage was possible, but this showed no advantage over the cationic polyelectrolytes.

### 1-Liter Settling Tests

One-liter settling tests were performed on samples taken from sampling points along Process Line No. 105, the Effluent Launders, and the Pelletizer Thickener overflow. Wastewater samples were initially screened through a 100-mesh sieve, and the resulting wastewater was mixed with an organic polymer (by inverting the cylinder after polymer addition) to promote flocculation. This was compared to a control sample which received the same degree of mixing but without the addition of flocculant. The settling rate of the solid-liquid

## Table 10

## Results of Preliminary Inorganic Flocculant Studies

| Jar Test Number | Chemicals | Dosage mg/l | pH | Flocculation Performance | Supernatant Quality | |
|---|---|---|---|---|---|---|
| | | | | | Turbidity JTU | SS mg/l |
| 1 | Lime | 100 | 11.0 | Fair | | |
| 2 | Lime | 200 | 11.2 | Good | 135 | 72 |
| 3 | Lime | 500 | 11.4 | Fair | | |
| 4 | Lime | 1,000 | 11.6 | Poor | | |
| 5 | None | -- | 8.3 | Very Poor | | |
| | | | | | | |
| 1 | None | -- | 8.3 | Poor | | |
| 2 | $FeCl_3$ | 50 | 6.6 | Good- Fast Settling Floc Clear Supernatant | 49 | |
| 3 | $FeCl_3$ | 100 | 4.8 | Fair | | |
| 4 | $FeCl_3$ | 200 | 3.4 | Poor | | |
| 5 | $FeCl_3$ | 500 | 2.8 | Poor | | |
| 6 | $FeCl_3$ | 1,000 | 2.4 | Poor | | |
| | | | | | | |
| 1 | $FeCl_3$ | 20 | 6.4 | Good | | |
| 2 | $FeCl_3$ | 40 | 6.7 | Good-Clear Supernatant | 90 | 39 |
| 3 | $FeCl_3$ | 60 | 5.8 | Fair | | |
| 4 | $FeCl_3$ | 80 | 5.4 | Poor | | |
| 5 | $FeCl_3$ | 100 | 5.0 | Poor | | |
| | | | | | | |
| 1 | Alum | -- | 8.3 | Poor | | |
| 2 | Alum | 25 | 7.6 | Good | 93.5 | |
| 3 | Alum | 50 | 7.4 | Good | | |
| 4 | Alum | 100 | 6.8 | Fair | | |
| 5 | Alum | 200 | 5.2 | Poor | | |
| 6 | Alum | 500 | 4.6 | Poor | | |
| | | | | | | |
| 1 | None | -- | 8.3 | Poor | 1,200 | 1,970 |
| 2 | $FeCl_3$ | 40 | 6.7 | Good | 30 | 31 |
| 3 | $FeCl_3$/Lime | 20/100 | 10.2 | Fair | | |
| 4 | $FeCl_3$/Lime | 10/50 | 9.8 | Fair | | |
| 5 | $FeCl_3$/Lime | 40/50 | 9.2 | Good | | |
| 6 | $FeCl_3$/Lime | 20/200 | 10.0 | Fair | | |
| | | | | | | |
| 1 | $FeCl_3$/Lime | 40/20 | 7.2 | | 18 | 12 |
| 2 | $FeCl_3$/Lime | 40/10 | 6.85 | | | |
| 3 | $FeCl_3$/Lime | 40/5 | 6.8 | | | |
| 4 | $FeCl_3$/Lime | 20/20 | 9.2 | | | |
| 5 | $FeCl_3$/Lime | 20/10 | 7.7 | | 55 | |
| 6 | $FeCl_3$/Lime | 20/5 | 7.5 | | | |

## Table 11

### Results of Preliminary Polyelectrolyte Flocculant Studies

| Jar Test Number | Chemical | Dosage mg/l | pH | Polyelectrolyte Performance | Supernatant Quality | |
|---|---|---|---|---|---|---|
| | | | | | Turbidity JTU | SS mg/l |
| 1 | None | | 8.3 | Poor | | |
| 2 | Dow A-23 | 2 | | Fair | | |
| 3 | Am. Cyanamid-863A | 2 | | Fair | | |
| 4 | Hercules Reten A-1 | 2 | | Poor | | |
| 5 | Dow A-23 | 1 | | Fair | | |
| 1 | None | | 8.3 | Poor | | |
| 2 | Dow N-12 | 2 | | Poor Some Floc | | |
| 3 | Atlas IN | 2 | | Poor Poor Supernatant | | |
| 4 | Am. Cyanamid-905N | 2 | | Poor | | |
| 1 | None | — | 8.3 | Poor | | |
| 2 | Dow C-31 | 10 | 8.2 | Fair<br>Good Settling Floc<br>Fair Supernatant | 126 | |
| 3 | Rohm and Haas C-7 | 2 | 8.1 | Fair | 150 | |
| 4 | Gendriv 158 | 2 | | Poor | | |
| 5 | Rohm and Haas C-7 | 1 | | Fair - Supernatant not as good as C-31 at 10 mg/l | | |
| 6 | Rohm and Haas C-7 | 1 | | Poor | | |
| 1 | None | — | | Poor | | |
| 2 | Dow PEI 600 | 2 | | Good | | |
| 3 | Dow PEI 600 | 5 | | Good | | |
| 4 | Dow PEI 1000 | 2 | | Good | | |
| 5 | Dow PEI 1000 | 2 | | Poor | | |
| 6 | Dow PEI 1090 | 2 | | Poor | | |
| | Dow PEI 1090 | 5 | | Poor | | |

Test Procedure: 100 rpm 30 seconds
15 rpm 5 minutes
Settling 15 minutes
NOTE: Solids settled before complete flocculation

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | Dow PEI 600 | 0.5 | 8.45 | | | |
| 2 | Dow PEI 600 | 1 | | | | |
| 3 | Dow PEI 600 | 2 | | | 80 | 29 |
| 4 | Dow PEI 600 | 3 | | | | |
| 5 | Dow PEI 600 | 4 | | | | |
| 6 | Dow PEI 600 | | | | | |

Test Procedure: 100 rpm 60 seconds
25 rpm 5 minutes
Settling 15 minutes
NOTE: It appeared that rapid flocculation was necessary to hold heavy solids in separation to achieve complete flocculation.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | Dow PEI 600 | 0.5 | 8.45 | Poor | | |
| 2 | Dow PEI 600 | 1 | | Fair | | |
| 3 | Dow PEI 600 | 2 | | Good | 12 | 12 |
| 4 | Dow PEI 1000 | 0.5 | | Poor | | |
| 5 | Dow PEI 1000 | 1 | | Fair | | |
| 6 | Dow PEI 1000 | 2 | | Good-Rapid Settling Clear Supernatant | 30 | |

Test Procedure: 100 rpm 60 seconds
75 rpm 5 minutes
Settling 15 minutes

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | Dow PEI 600/Dow A-23 | 1.0/0.25 | | Very good | | |
| 2 | Dow PEI 600/Dow A-23 | 1.0/0.5 | | | | |
| 3 | Dow PEI 600/Dow A-23 | 1.0/1.0 | | | | |
| 4 | Dow PEI 600/Dow A-23 | 2.0/0.25 | | | | |
| 5 | Dow PEI 600/Dow A-23 | 2.0/0.5 | | | | |
| 6 | Dow PEI 600/Dow A-23 | 2.0/1.0 | | | | |

Sequence: Both added together

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | Dow PEI 600/Dow A-23 | 1.0/0.25 | | | | |
| 2 | Dow PEI 600/Dow A-23 | 1.0/0.5 | | | | |
| 3 | Dow PEI 600/Dow A-23 | 7.0/0.25 | | | | |
| 4 | Dow PEI 600/Dow A-23 | 2.0/0.5 | | | | |

Test Procedure: 100 rpm 60 seconds with PEI 600 only
75 rpm 5 minutes with PEI 600 only
100 rpm 30 seconds Both PEI 600 and A-23
75 rpm 5 minutes Both PEI 600 and A-23
Settling 15 minutes

Table 11
(continued)

| Jar Test Number | Chemical | Dosage mg/l | pH | Polyelectrolyte Performance | Supernatant Quality Turbidity JTU | Supernatant Quality SS mg/l |
|---|---|---|---|---|---|---|
| 1 | Dow PEI 600 | 1.0 | | | | |
| 2 | Dow PEI 600 | 2.0 | | Best of group-Good Supernatant<br>Good Supernatant | 6.5 | 10 |
| 3 | Dow PEI 1090 | 1.0 | | | | |
| 4 | Dow PEI 1090 | 2.0 | | | 11.0 | |
| 5 | Calgon M-500 | 1.0 | | | | |
| 6 | Calgon M-500 | 2.0 | | | 52 | 10 |
| Test Procedure: | 100 rpm | 60 seconds | | | | |
| | 75 rpm | 5 minutes | | | | |
| | Settling | 15 minutes | | | | |
| 1 | Dow PEI 600 | 1 | | | | |
| 2 | Dow PEI 600 | 2 | | | | |
| 3 | Nalco 603 | 10 | | | 49 | |
| 4 | Nalco 603 | 20 | | | | |
| 5 | Dow PEI 1000 | 1 | | | | |
| 6 | Dow PEI 1000 | 2 | | | 35 | 16 |
| Test Procedure: | 100 rpm | 60 seconds | | | | |
| | 75 rpm | 5 minutes | | | | |
| | Settling | 15 minutes | | | | |
| 1 | Nalco 603 | 2.5 | | | | |
| 2 | Nalco 603 | 5 | | Not as good as 10 mg/l | | |
| 1 | Dow C-31 | 1 | | Poor | | |
| 2 | Dow C-31 | 2 | | Fair | 52 | |
| 3 | Rohm and Haas C-7 | 1 | | Fair | | |
| 4 | Rohm and Haas C-7 | 2 | | Best of group-Rapid Settling | 43 | 4 |
| 5 | Gendriv 158 | 1 | | Poor | | |
| 6 | Gendriv 158 | 2 | | Poor | | |
| 1 | Dow A-23 | 2 | | Unsatisfactory-Poor Supernatant | | |
| 2 | Am. Cyanamid 836-A | 2 | | Unsatisfactory-Poor Supernatant | | |
| 3 | Hercules Reten A-1 | 2 | | Unsatisfactory-Poor Supernatant | | |
| 4 | Dow N-12 | 2 | | Unsatisfactory-Poor Supernatant | | |
| 5 | Atlas IN | 2 | | Unsatisfactory-Poor Supernatant | | |
| 6 | Am. Cyanamid 905 N | 2 | | Unsatisfactory-Poor Supernatant | | |
| 1 | Dow PEI 600 | 1 | | | 63 | 19 |
| 2. | Dow PEI 1000 | 1 | | | 63 | 16 |
| 3 | Dow PEI 1090 | 1 | | | 76 | 18 |
| 4 | Nalco 603 | 10 | | Settles quickly | | |
| 5 | Calgon M-500 | 1 | | | | |
| 6 | Rohm and Haas C-7 | 1 | | Settles quickly | 70 | 14 |
| Test Procedure: | 100 rpm | 60 seconds | | | | |
| | 75 rpm | 5 minutes | | | | |
| | Settling | 15 minutes | | | | |
| | (Most solids settled in 3 minutes) | | | | | |
| 1 | Nalco 603 | 1 | | Settles quickly | 37.5 | |
| 2 | Dow C-31 | 1 | | Settles quickly | 52 | |
| 3 | Calgon M-500 | 1 | | | 66 | 9 |
| 4 | None | — | | | 2,000 | 1,980 |
| 1 | PEI 600 | 0.5 | | | | |
| 2 | PEI 600 | 1.0 | | | | 12 |
| 3 | PEI 600 | 2.0 | | Best of group | | |
| 4 | Nalco 603 | 0.5 | | | | |
| 5 | Nalco 603 | 1.0 | | | | |
| 6 | Nalco 603 | 2.0 | | | | |

interface was measured, and samples of the clarified supernatant were taken at various times for analysis. The settling rates and suspended solids content of each treated wastewater and control sample are shown graphically in Figures 1 through 8. In none of these tests did the control sample exhibit a clear solids-liquid interface, while, with the exception of one sample, the treated samples showed a significantly higher rate of interface settling and a much better supernatant quality. The settling test results on treated Hydroseparator overflow were similiar to the control sample; however, less than an optimum dosage of PEI 600 was used in this particular test.

### 8-Foot Column Settling Tests

Determination of theoretical settling rates of flocculated suspended solids are relatively difficult to calculate, because of the changes in size, shape, and weight of the particles resulting from the flocculation process. Consequently, it is necessary to evaluate settling rates experimentally. The data necessary to evaluate the settling rates can be obtained from one-liter settling tests or by eight-foot column settling tests. The larger column-settling test apparatus generally provide better data for scale-up purposes. However, it should be noted that a number of problems were encountered with the eight-foot column tests during this study, and more emphasis is being placed on the results of one-liter settling tests discussed previously.

The test procedure followed in the eight-foot column test was to place 20 gallons of <100-mesh East Launder tailings into a large container to which polyelectrolyte was added. The contents were then mixed to promote flocculation. No flocculant was added in Tests No. 1 and No 2, although a similar amount of mixing was provided. The wastewater was transferred into the column using a submersible pump. As soon as all the wastewater was transferred and the column was filled, the settling test was initiated. Samples from the one-, three-, five-, and seven-foot levels (measured from the surface) were collected in individual bottles at pre-determined time intervals for suspended solids analyses. The results of these analyses are shown in Table 12.

The two best cationic polymers as determined from the preliminary polyelectrolyte flocculation tests (Dow PEI 600 and Calgon M-500) were used in this study. The results of these tests indicated that Dow PEI 600 was capable of providing a better effluent quality than Calgon M-500. The optimum dosage for PEI 600 was apprxoimately 2 mg/l, with a large difference in effectiveness occuring between 1 and 2 mg/l dosages, but little difference in the results indicated between the 2 and 4 mg/l dosages.

The results of the eight-foot column test were considered less reliable than the results obtained in the one-liter tests. The inability to provide rapid flocculation to the wastewater before it entered the eight-foot column, the shearing of flocculated particles in transferring wastewater from the mixing container to the column and the lack of adequate flocculation in the column itself hindered optimum flocculation and settling. The temperature gradient experienced in Run No. 1 led to very poor results, although the problem was partially overcome by allowing the wastewater to come to ambient temperature before running the test. It is felt that in actual operation solids removal will reflect more closely the results of the one-liter test rather than the results of eight-foot column tests.

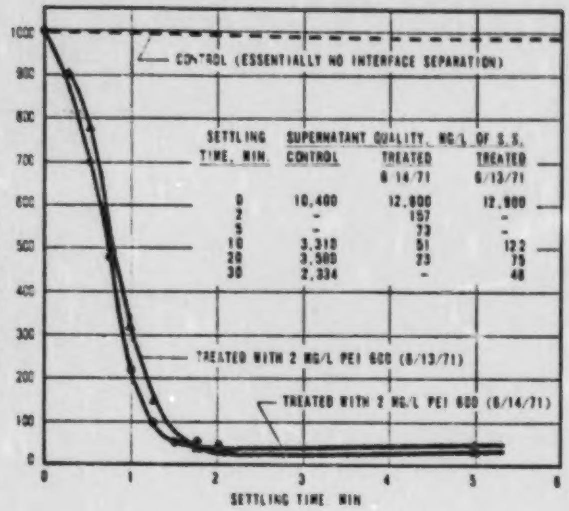
### Sludge Thickening

Twenty-gallon samples were collected from the East Launder and filtered through a 100-mesh sieve; material larger than 100-mesh was discarded. The wastewater passing the

### FIGURE 1

INTERFACE SETTLING RATE

MINUS 100 MESH EAST LAUNDER TAILINGS

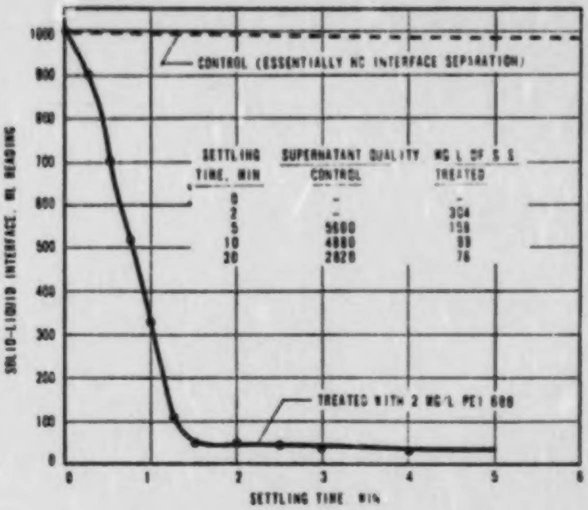


| SETTLING TIME, MIN. | SUPERNATANT QUALITY, MG/L OF S.S. CONTROL | TREATED 6/14/71 | TREATED 6/13/71 |
|---|---|---|---|
| 0 | 10,400 | 12,800 | 12,900 |
| 2 | - | 157 | - |
| 5 | - | 73 | - |
| 10 | 3,310 | 51 | 122 |
| 20 | 3,500 | 23 | 75 |
| 30 | 2,334 | - | 48 |

### FIGURE 2

INTERFACE SETTLING RATE

MINUS 100 MESH WEST LAUNDER TAILINGS

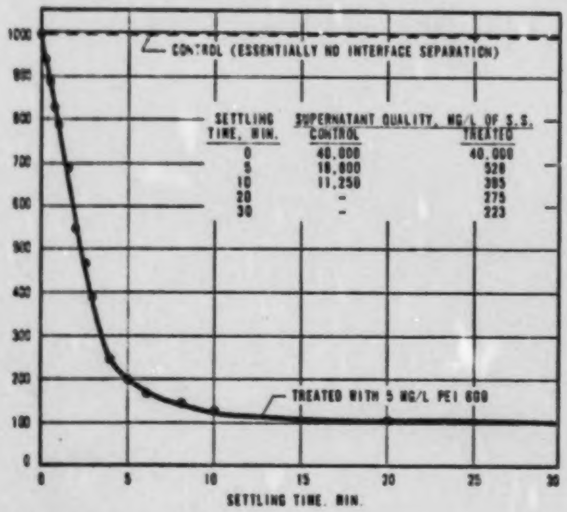


| SETTLING TIME, MIN | SUPERNATANT QUALITY MG/L OF S.S. CONTROL | TREATED |
|---|---|---|
| 0 | - | - |
| 2 | - | 304 |
| 5 | 5600 | 158 |
| 10 | 4880 | 99 |
| 20 | 2820 | 76 |

### FIGURE 3

INTERFACE SETTLING RATE

MINUS 100 MESH COBBER TAILINGS

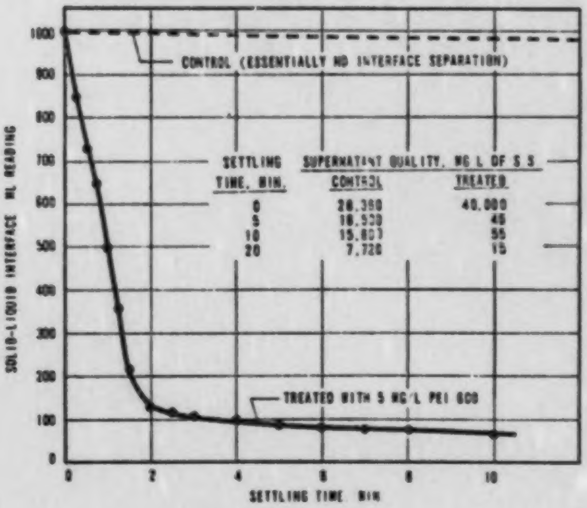


| SETTLING TIME, MIN. | SUPERNATANT QUALITY, MG/L OF S.S. CONTROL | TREATED |
|---|---|---|
| 0 | 40,000 | 40,000 |
| 5 | 18,800 | 528 |
| 10 | 11,250 | 385 |
| 20 | - | 275 |
| 30 | - | 223 |

### FIGURE 4

INTERFACE SETTLING RATE

MINUS 100 MESH ROUGHER TAILINGS



| SETTLING TIME, MIN. | SUPERNATANT QUALITY, MG/L OF S.S. CONTROL | TREATED |
|---|---|---|
| 0 | 28,350 | 40,000 |
| 5 | 18,930 | 45 |
| 10 | 15,807 | 55 |
| 20 | 7,720 | 15 |

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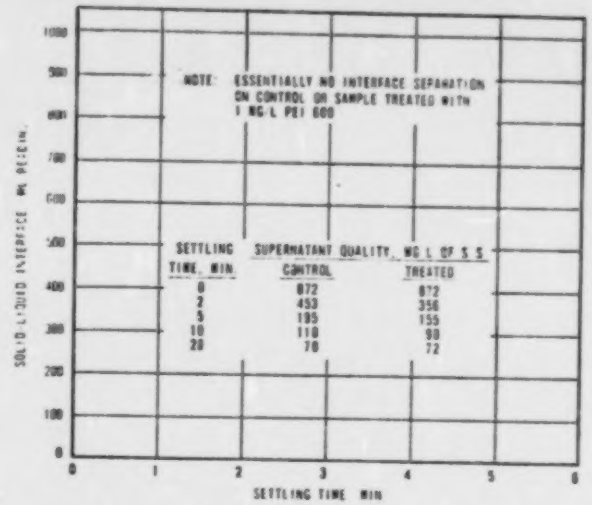
### FIGURE 5

### INTERFACE SETTLING RATE

### MINUS 100 MESH HYDROSEPARATOR OVERFLOW



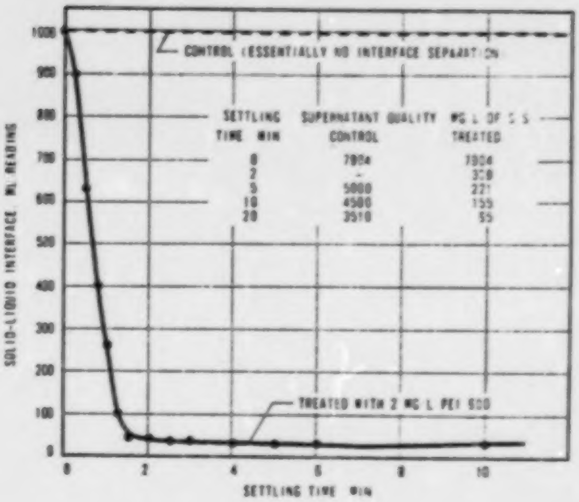
NOTE: ESSENTIALLY NO INTERFACE SEPARATION ON CONTROL OR SAMPLE TREATED WITH 1 MG/L PEI 600

| SETTLING TIME, MIN. | SUPERNATANT QUALITY, MG/L OF S.S. CONTROL | TREATED |
|---|---|---|
| 0 | 872 | 872 |
| 2 | 453 | 356 |
| 5 | 195 | 155 |
| 10 | 110 | 90 |
| 20 | 70 | 72 |

### FIGURE 6

### INTERFACE SETTLING RATE

### MINUS 100 MESH FINISHER TAILINGS

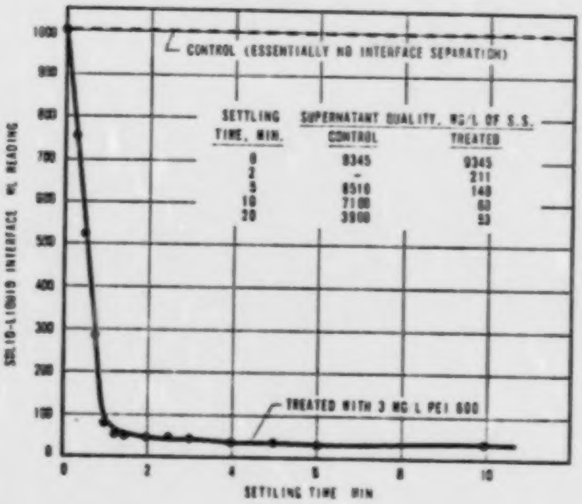


| SETTLING TIME MIN | SUPERNATANT QUALITY MG/L OF S.S. CONTROL | TREATED |
|---|---|---|
| 0 | 7904 | 7904 |
| 2 | - | 300 |
| 5 | 5000 | 221 |
| 10 | 4500 | 155 |
| 20 | 3510 | 55 |

### FIGURE 7

### INTERFACE SETTLING RATE

### MINUS 100 MESH SIPHONSIZER OVERFLOW

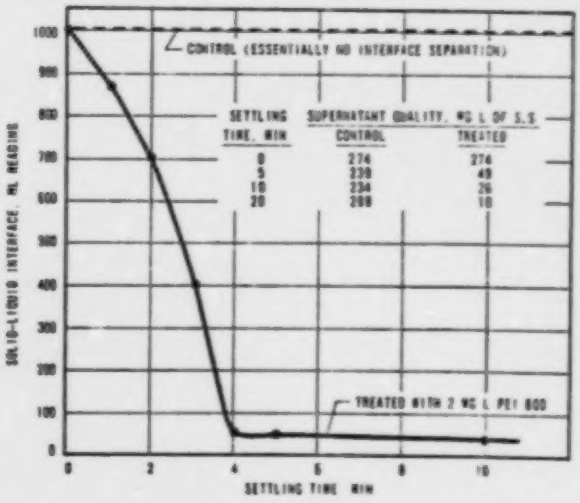


| SETTLING TIME, MIN. | SUPERNATANT QUALITY, MG/L OF S.S. CONTROL | TREATED |
|---|---|---|
| 0 | 9345 | 9345 |
| 2 | - | 211 |
| 5 | 8510 | 140 |
| 10 | 7100 | 60 |
| 20 | 3900 | 53 |

### FIGURE 8

### INTERFACE SETTLING RATE

### MINUS 100 MESH PELLETIZER THICKENER OVERFLOW



| SETTLING TIME, MIN | SUPERNATANT QUALITY, MG/L OF S.S. CONTROL | TREATED |
|---|---|---|
| 0 | 274 | 274 |
| 5 | 230 | 49 |
| 10 | 234 | 26 |
| 20 | 200 | 10 |

## Table 12

### Results of Eight-Foot Column Settling Tests on <100 Mesh East Launder Tailings

| Run No. | Polyelectrolyte | Dosage mg/l | Settling Time minutes | Depth of Sample feet | Suspended Solids Concentration mg/l | Suspended Solids Remaining percent |
|---|---|---|---|---|---|---|
| 1 | None | 0 | 0 | – | 12,287 | |
| | | | 10 | 1 | 6,987 | 56.8 |
| | | | 10 | 3 | 10,670 | 87.0 |
| | | | 10 | 5 | 12,010 | 97.6 |
| | | | 10 | 7 | 11,418 | 93.0 |
| | | | 20 | 1 | 5,033 | 46.0 |
| | | | 20 | 3 | 8,428 | 68.6 |
| | | | 20 | 5 | 10,024 | 82.0 |
| | | | 20 | 7 | 11,355 | 92.5 |
| | | | 30 | 1 | 4,099 | 33.0 |
| | | | 30 | 3 | 8,076 | 66.0 |
| | | | 30 | 5 | 9,393 | 76.4 |
| | | | 30 | 7 | 9,847 | 80.0 |
| | | | 60 | 1 | 2,713 | 22.0 |
| | | | 60 | 3 | 5,368 | 43.5 |
| | | | 60 | 5 | 4,915 | 40.0 |
| | | | 60 | 7 | 3,137 | 25.5 |
| | | | 90 | 1 | 2,100 | 17.1 |
| | | | 90 | 3 | 3,739 | 30.5 |
| | | | 90 | 5 | 2,295 | 18.7 |
| | | | 90 | 7 | 7,107 | 57.0 |
| | | | 120 | 1 | 1,729 | 14.1 |
| | | | 120 | 3 | 2,822 | 23.0 |
| | | | 120 | 5 | 4,334 | 35.2 |
| | | | 120 | 7 | 6,029 | 49.2 |
| 2 | None | 0 | 0 | – | 16,920 | |
| | | | 10 | 1 | 6,795 | 40.1 |
| | | | 10 | 3 | 10,593 | 62.6 |
| | | | 10 | 5 | 12,410 | 73.4 |
| | | | 10 | 7 | 13,016 | 76.9 |
| | | | 20 | 1 | 4,522 | 26.7 |
| | | | 20 | 3 | 8,393 | 49.6 |
| | | | 20 | 5 | 10,398 | 61.5 |
| | | | 20 | 7 | 11,135 | 65.8 |
| | | | 30 | 1 | 4,178 | 24.7 |
| | | | 30 | 3 | 6,909 | 40.8 |
| | | | 30 | 5 | 8,125 | 48.0 |
| | | | 30 | 7 | 10,098 | 59.8 |
| | | | 60 | 1 | 2,823 | 16.7 |
| | | | 60 | 3 | 5,363 | 31.9 |
| | | | 60 | 5 | 7,055 | 41.7 |
| | | | 60 | 7 | 8,021 | 47.4 |
| | | | 90 | 1 | 2,074 | 12.2 |
| | | | 90 | 3 | 4,248 | 25.1 |
| | | | 90 | 5 | 5,929 | 35.0 |
| | | | 90 | 7 | 6,998 | 41.4 |
| | | | 120 | 1 | 2,057 | 12.2 |
| | | | 120 | 3 | 2,761 | 16.3 |
| | | | 120 | 5 | 5,091 | 30.1 |
| | | | 120 | 7 | 6,175 | 36.5 |
| 3 | PEI 600 | 2.0 | 0 | – | 19,700 | |
| | | | 2 | 1 | 1,398 | 7.1 |
| | | | 2 | 3 | 1,779 | 9.0 |
| | | | 2 | 5 | 9,748 | 49.5 |
| | | | 2 | 7 | 18,882 | 95.5 |
| | | | 5 | 1 | 528 | 2.7 |
| | | | 5 | 3 | 774 | 3.9 |
| | | | 5 | 5 | 1,269 | 6.4 |
| | | | 5 | 7 | 2,757 | 14.0 |
| | | | 15 | 1 | 188 | 0.95 |
| | | | 15 | 3 | 191 | 0.97 |
| | | | 15 | 5 | 176 | 0.90 |
| | | | 15 | 7 | 174 | 0.89 |
| | | | 30 | 1 | 47 | 0.24 |
| | | | 30 | 3 | 111 | 0.56 |
| | | | 30 | 5 | 96 | 0.49 |
| | | | 30 | 7 | 96 | 0.49 |
| | | | 45 | 1 | 56 | 0.28 |
| | | | 45 | 3 | 83 | 0.42 |
| | | | 45 | 5 | 67 | 0.34 |
| | | | 45 | 7 | 66 | 0.34 |
| | | | 60 | 1 | 51 | 0.26 |
| | | | 60 | 3 | 79 | 0.40 |
| | | | 60 | 5 | 59 | 0.30 |
| | | | 60 | 7 | 63 | 0.32 |

Table 12
(continued)

| Run No. | Polyelectrolyte | Dosage mg/l | Settling Time minutes | Depth of Sample feet | Suspended Solids Concentration mg/l | Suspended Solids Remaining percent |
|---|---|---|---|---|---|---|
| 4 | PEI 600 | 1.0 | 0 | - | 14,179 | |
| | | | 2 | 1 | 973 | 6.9 |
| | | | 2 | 3 | 1,639 | 11.5 |
| | | | 2 | 5 | 15,163 | 100+ |
| | | | 2 | 7 | 18,154 | 100+ |
| | | | 5 | 1 | 841 | 5.9 |
| | | | 5 | 3 | 1,151 | 8.1 |
| | | | 5 | 5 | 2,293 | 16.2 |
| | | | 5 | 7 | 15,837 | 100+ |
| | | | 15 | 1 | 476 | 3.4 |
| | | | 15 | 3 | 547 | 3.9 |
| | | | 15 | 5 | 664 | 4.7 |
| | | | 15 | 7 | 1,280 | 9.0 |
| | | | 30 | 1 | 276 | 1.9 |
| | | | 30 | 3 | 355 | 2.5 |
| | | | 30 | 5 | 434 | 3.0 |
| | | | 30 | 7 | 511 | 3.6 |
| | | | 45 | 1 | 228 | 1.6 |
| | | | 45 | 3 | 286 | 2.0 |
| | | | 45 | 5 | 307 | 2.2 |
| | | | 45 | 7 | 319 | 2.3 |
| | | | 60 | 1 | 168 | 1.2 |
| | | | 60 | 3 | – | – |
| | | | 60 | 5 | 241 | 1.7 |
| | | | 60 | 7 | 262 | 1.8 |
| 5 | PEI 600 | 4.0 | 0 | - | 10,980 | |
| | | | 2 | 1 | 759 | 6.9 |
| | | | 2 | 3 | 1,116 | 10.1 |
| | | | 2 | 5 | 3,511 | 32.0 |
| | | | 2 | 7 | 8,478 | 77.0 |
| | | | 5 | 1 | 356 | 3.2 |
| | | | 5 | 3 | – | – |
| | | | 5 | 5 | 329 | 3.8 |
| | | | 5 | 7 | 535 | 4.9 |
| | | | 15 | 1 | 137 | 1.2 |
| | | | 15 | 3 | 142 | 1.3 |
| | | | 15 | 5 | 107 | 0.98 |
| | | | 15 | 7 | 139 | 1.3 |
| | | | 30 | 1 | 74 | 0.67 |
| | | | 30 | 3 | 90 | 0.82 |
| | | | 30 | 5 | 92 | 0.83 |
| | | | 30 | 7 | 101 | 0.92 |
| | | | 45 | 1 | 63 | 0.57 |
| | | | 45 | 3 | 28 | 0.25 |
| | | | 45 | 5 | 16 | 0.15 |
| | | | 45 | 7 | 80 | 0.73 |
| | | | 60 | 1 | 49 | 0.45 |
| | | | 60 | 3 | 59 | 0.54 |
| | | | 60 | 5 | 59 | 0.54 |
| | | | 60 | 7 | 66 | 0.60 |
| 6 | Calgon M-500 | 1.0 | 0 | - | 14,458 | |
| | | | 2 | 1 | 3,931 | 27.2 |
| | | | 2 | 3 | 6,643 | 45.8 |
| | | | 2 | 5 | 14,134 | 98.0 |
| | | | 2 | 7 | 15,691 | 100+ |
| | | | 5 | 1 | 3,029 | 21.0 |
| | | | 5 | 3 | 4,845 | 33.5 |
| | | | 5 | 5 | 9,449 | 65.5 |
| | | | 5 | 7 | 13,174 | 91.0 |
| | | | 15 | 1 | 1,851 | 12.8 |
| | | | 15 | 3 | 2,623 | 18.2 |
| | | | 15 | 5 | 4,029 | 27.9 |
| | | | 15 | 7 | 3,852 | 26.7 |
| | | | 30 | 1 | 1,153 | 8.0 |
| | | | 30 | 3 | 690 | 4.8 |
| | | | 30 | 5 | 2,346 | 16.2 |
| | | | 30 | 7 | 3,184 | 22.0 |
| | | | 45 | 1 | – | – |
| | | | 45 | 3 | 896 | 6.2 |
| | | | 45 | 5 | 1,286 | 8.9 |
| | | | 45 | 7 | 3,883 | 26.9 |
| | | | 60 | 1 | 834 | 5.8 |
| | | | 60 | 3 | 689 | 4.8 |
| | | | 60 | 5 | 1,131 | 7.8 |
| | | | 60 | 7 | 1,314 | 9.1 |

Table 12
(continued)

| Run No. | Polyelectrolyte | Dosage mg/l | Settling Time minutes | Depth of Sample feet | Suspended Solids Concentration mg/l | Suspended Solids Remaining percent |
|---|---|---|---|---|---|---|
| 7 | Calgon M-500 | 2.0 | 0 | – | 11,533 | |
| | | | 2 | 1 | 1,723 | 15.0 |
| | | | 2 | 3 | 1,703 | 14.8 |
| | | | 2 | 5 | 9,424 | 81.8 |
| | | | 2 | 7 | 13,304 | 100+ |
| | | | 5 | 1 | 1,020 | 8.9 |
| | | | 5 | 3 | 1,087 | 9.4 |
| | | | 5 | 5 | 1,496 | 13.0 |
| | | | 5 | 7 | 13,303 | 100+ |
| | | | 15 | 1 | 419 | 3.6 |
| | | | 15 | 3 | 469 | 4.1 |
| | | | 15 | 5 | 613 | 5.3 |
| | | | 15 | 7 | 600 | 5.2 |
| | | | 30 | 1 | 268 | 2.3 |
| | | | 30 | 3 | 298 | 2.6 |
| | | | 30 | 5 | 328 | 2.9 |
| | | | 30 | 7 | 4,151 | 36.0 |
| | | | 45 | 1 | 176 | 1.5 |
| | | | 45 | 3 | 227 | 2.0 |
| | | | 45 | 5 | 262 | 2.3 |
| | | | 45 | 7 | 220 | 1.9 |
| | | | 60 | 1 | 142 | 1.2 |
| | | | 60 | 3 | 199 | 1.7 |
| | | | 60 | 5 | 208 | 1.8 |
| | | | 60 | 7 | 193 | 1.7 |
| 8 | Calgon M-500 | 4.0 | 0 | – | 6,220 | |
| | | | 2 | 1 | 1,322 | 21.3 |
| | | | 2 | 3 | 1,503 | 24.2 |
| | | | 2 | 5 | 2,653 | 42.9 |
| | | | 2 | 7 | 13,655 | 100+ |
| | | | 5 | 1 | 816 | 13.1 |
| | | | 5 | 3 | 1,136 | 18.3 |
| | | | 5 | 5 | – | – |
| | | | 5 | 7 | 9,622 | 100+ |
| | | | 15 | 1 | 407 | 6.5 |
| | | | 15 | 3 | 452 | 7.3 |
| | | | 15 | 5 | 607 | 9.7 |
| | | | 15 | 1 | 769 | 12.4 |
| | | | 30 | 1 | 231 | 3.7 |
| | | | 30 | 3 | 333 | 5.3 |
| | | | 30 | 5 | 359 | 5.8 |
| | | | 30 | 7 | 476 | 7.7 |
| | | | 45 | 1 | 126 | 2.0 |
| | | | 45 | 3 | 50 | 0.80 |
| | | | 45 | 5 | 337 | 5.4 |
| | | | 45 | 7 | 333 | 5.4 |
| | | | 60 | 1 | 153 | 2.5 |
| | | | 60 | 3 | 240 | 3.9 |
| | | | 60 | 5 | 239 | 3.9 |
| | | | 60 | 7 | 279 | 4.5 |

100-mesh sieve was treated with Dow PEI 600 at a dosage of 2 mg/l. Rapid mixing, followed by a settling time of 15 minutes, was provided. Supernatant was drawn off to waste, and the settled sludge was collected. Four gallons of this settled sludge were shipped to the ROY F. WESTON laboratories in West Chester, Pennsylvania to determine thickening characteristics.

Gravity thickening tests were performed in a one-liter graduated cylinder without any additional flocculation or chemical addition. The results of these tests indicated that the sludge could be concentrated from approximately 26 percent solids to approximately 54 percent solids in a period of 60 minutes.

### Sludge Dewatering

The two most widely used methods of dewatering wastewater sludges are vacuum filtration and centrifugation. At the present time, reliable laboratory-scale procedures are available only for the evaluation of sludge dewatering by the vacuum filtration process. Laboratory evaluation of centrifugation is only a qualitative test, and reliable data for design purposes generally requires pilot or full-scale studies.

Vacuum filtration studies were conducted on the thickened sludge using the Buchner funnel test procedure. The results of these tests are presented in Table 13 and indicate that the addition of additional polyelectrolytes does not significantly increase the dewatering rate of this sludge. The dewatering rates, however, were very high, indicating application of a leaf filter or possibly a top-load filter, rather than a drum type vacuum filter. Also, the qualitative results from the centrifugation studies indicated that centrifugation would produce a soft, wet sludge cake and a cloudy supernatant even with a long residence time. Therefore, this sludge dewatering procedure does not appear to warrant further evaluation.

Table 13

Results of Vacuum Filtration Buchner Funnel Studies[1]

| Test No. | Polyelectrolyte Added | Dosage Volume ml | Dosage Concentration percent | Vacuum in. Hg | Specific Resistance units | Cake Moisture percent | Filter Yield lbs. sq.ft. hr. |
|---|---|---|---|---|---|---|---|
| 1 | None | – | — | 20 | $6.23 \times 10^6$ | 27.7 | 165 |
| 2 | None | – | — | 20 | $3.74 \times 10^6$ | 27.2 | 309 |
| 3 | Dow A-23 | 1 | 0.1 | 20 | $5.24 \times 10^6$ | 30.6 | 220 |
| 4 | Dow A-23 | 2 | 0.1 | 20 | $4.74 \times 10^6$ | 30.2 | 243 |
| 5 | Dow N-12 | 2 | 0.1 | 20 | $7.54 \times 10^6$ | — | 153 |
| 6 | Dow PEI 600 | 2 | 0.1 | 20 | $10.14 \times 10^6$ | 27.8 | 113 |
| 7 | None | – | — | 20 | $8.06 \times 10^6$ | 23.5 | 143 |
| 8 | None | – | — | 15 | $13.0 \times 10^6$ | 27.3 | 86 |
| 9 | None | – | — | 15 | $9.88 \times 10^6$ | 28.2 | 117 |

[1] Initial sludge volume was 100 ml except for Tests 7 and 8 which used 50 ml of sludge.

## Tailings Utilization and Recovery

The utilization of Reserve Mining tailings in the construction industry for fabrication of building materials, landfill, landscaping, recreation area construction, or the formation of water-impoundment areas have been suggested as solutions for partial or total disposal of the tailings waste currently generated. This section includes a description of the proposals and ideas forwarded, and discusses the conditions that will have to be taken into account, as well as potential problems that may ensue. Reserve Mining included two such tailings utilization proposals in its Engineering Task Force study.

### Small Boat Harbor and Swimming Area Construction

This scheme would utilize tailings to build up the bottom of a small artificial bay near Gull Island, southwest of Reserve Mining's Silver Bay plant. The bay would be 15 feet deep and would include a breakwater, swimming area, boat launching facilities, docks, parking lots, and landscaping. The project would utilize only about 5.5 million tons of tailings (one-fourth of a yearly tailings discharge).

The quantity of tailings utilized is small in relation to the quantity to be disposed of. No mention of the size range of tailings to be usediis made, but it can be assumed that fine tailings which would not remain settled under the wave and current conditions generated by boating would be separated prior to filling. A breakwater to protect the harbor would be constructed of large rock fill. No tailings would be utilized in breakwater construction.

The Governor's office has expressed an interest in a similar project that would be constructed as part of a small-boat harbor network on Minnesota's northwest shore of Lake Superior. Boating is extremely popular and, with improved facilities, is expected to continue its growth in that area. The Corps of Engineers would handle the construction of the facilities on a cost-sharing basis with State and local interests.

No detailed cost figures are available at this time, but it is estimated that construction costs of the facilities would be in the range of 1 to 1.5 million dollars. Land for the project would be donated by Reserve Mining Company.

### Sand and Aggregate Markets

Proposal No. 19 of the Reserve Engineering Task Force report, "The Analysis and Markets of Taconite Waste Products" by Arthur D. Little, Inc., examined the marketability of tailings waste in the Great Lakes area. The products marketed would include sand and gravel for construction, paving, landfill, railroad ballast, and other applications. The conclusions about the amount of taconite waste that might be marketed in the Great Lakes Region is based on projections of the trends in sand and gravel demand and production as developed by the U.S. Bureau of Mines. It is also based on field study and interviews with sand and gravel operators and ready-mix producers in Chicago, Cleveland, Detroit, Buffalo, Minneapolis, St. Paul, Toronto, Milwaukee, Erie, and Toledo, and other studies by the Bureau of Mines and by the National Sand and Gravel Association, Silver Spring, Maryland.

The summary of the Task Force report indicated that the total current market (1970) for sand in eight lakeside Standard Metropolitan Statistical Areas (SMSA) and in Minneapolis-St. Paul is about 21,000,000 net tons and that the coarse aggregate market for this same area is about 22,000,000 net tons.

According to the Arthur D. Little study, the portion of the sand market that Reserve Mining could supply in individual markets varied from 4 to 13 percent. No conclusions were drawn about the amount of gravel that could be marketed. However, the overall average quantity of sand that the region could absorb was estimated to be 5 percent of the present market. This would constitute only about 1.2 million tons of taconite waste, or 6 percent of the tailings produced. The annual costs and revenues of operating a tailings recovery, screening, and shipping operation as developed in the Arthur D. Little study, are summarized in Table 14.

A brief mention was made of large projects such as the proposed Chicago Island Airport. One or several such projects requiring major contracts for 50,000 tons/day or more of sand and smaller amounts of gravel could establish Reserve Mining Co. in the sand and gravel business. This, however, would be only a temporary solution because a project on the scale of the Chicago Island Airport is rare, the environmental issues surrounding it are of an extremely controversial nature, and there is no guarantee that it would be constructed.

The Arthur D. Little report did not include projection of market growth as affected by economic growth in the region under consideration, growth in the new population centers, continued building cost inflation, changes in national transportation policy, public projects backlog, and other government spending.

Growth of the market at 2 to 4 percent per year would enable Reserve Mining to increase its market share gradually to fill the new portion of the demand. There is every possibility that a large supplier such as Reserve could, in a short time, dominate the sand and gravel markets within short distances of the Lower Great Lakes Ports. If, during the period of an expanding economy (with an assumed high construction volume) Reserve were to start underselling the market, it could win a major portion of the demand. Buyers would rapidly discover that competitive production and delivery costs do not apply to Reserve, which would be essentially dumping material on the market at substantially lower costs. This could result in a deficit for Reserve Mining for the sand and gravel and related operations per se, but the net outlay would certainly be less than the cost of on-land disposal of the coarse tailings. Furthermore, the use of tailings for sand and aggregate, as an alternative to disposal, would be desirable from an environmental standpoint because it would reduce the extent of the tailings disposal site, conserve other sand and gravel resources, and recycle a beneficial material.

One of the most favorable conditions for disposal of tailings would be to enter into long-term contracts with government agencies to supply a pre-determined amount of the required sand and gravel over a number of years at some agreed upon price. This would give an assurance of tailings disposal without affecting markets and employment as readily as suggested. The risk involved in entering the sand and gravel markets would also be reduced.

The total cost of disposing of tailing wastes that are not marketable would pose a major problem in the initial years of operation. A system for conveying or transporting the remaining material to an on-land disposal site may have to be constructed, along with process changes that would be required for separation and sizing of usable tailings.

## Table 14

## Annual Costs and Revenues from Sales of Sand at Lower Great Lakes Ports

Tailings Recovery Plant Located on Delta ($775,000 Capital Cost)
(2.0 million tons/year, plant operating 9 months/year,
6 days/week, 15 hours/day)

| | | |
|---|---|---|
| Annual Costs | | |
| Labor and Associated Costs (2 men) | $ 27,000 | |
| Power at 860 HP and Lighting $.01/KWH, 50 percent Ore | 17,500 | |
| Maintenance Supplies and Labor | 43,500 | |
| Depreciation on $775,000 plant (20 years) | 38,800 | |
| Sub-total | $ 126,800 | |
| Contingency at 12 percent | 15,000 | |
| Total Annual Costs of Tailings Recovery | | $141,800 |

Screening and Storage Plant (Capital Cost - $850,000)
(1.1 million tons/year, operating 9 months/year)

| | | |
|---|---|---|
| Annual Costs | | |
| Labor and Associated Costs (5 men) | $ 80,000 | |
| Power at 400 HP, $.01/KWH, 80 percent use | 13,000 | |
| Maintenance and Supplies | 50,000 | |
| Depreciation $850,000 (10 percent) | 85,000 | |
| Sub-total | $ 228,000 | |
| Contingency | 37,000 | |
| Total Annual Costs of Screening and Storage | | $265,000 |
| ANNUAL COST OF SAND RECOVERY AND PREPARATION | | $407,000 |

| | |
|---|---|
| Cost per Ton (Based on 1.1 million tons/year) | $0.37 |
| Average Shipping Cost to Lower Lake Ports (to Rail of Vessel) per Ton | 2.08 |
| Delivered Cost per Ton | $2.45 |

| | |
|---|---|
| TOTAL ANNUAL REVENUE (Based on Current Dockside Cost of $1.75 to $2.00 per Ton) | $2,195,000 |
| TOTAL ANNUAL COSTS (at $2.45 per Ton) | 3,020,000 |
| ANNUAL LOSS | $ 825,000 |

Source: Arthur D. Little report entitled "Analysis and Markets of Taconite Waste Products".

## Fabrication of Bricks and Building Blocks

ROY F. WESTON, in an attempt to find a beneficial use of tailings, contacted Tekology Corporation of Palisades Park, New Jersey to determine the properties of bricks made of taconite tailings by utilizing cement and an organic material in a cold curing process developed and currently marketed by Tekology Corporation. Bricks fabricated by Tekology from tailings collected at Reserve Mining Company were tested by the fabricator for compressive strength and water adsorption. These two tests are the main parameters for conventional clay brick. The results of the tests are shown in Table 15.

Table 15

Qualities of Taconite Brick

| Compressive Strength psi | Water Absorption percent |
|---|---|
| 6,250 | 6.68 |
| 7,250 | 6.90 |
| 5,500 | 7.76 |

The parameters measured on the taconite bricks are superior to conventional brick. By comparison, the highest grade clay brick has minimum requirements of 3,000 psi compressive strength and 8.2 percent water absorption; whereas, concrete block minimums are 3,500 psi compressive strength and 8.2 percent absorption.

The sample bricks made of Taconite tailings and a 10 percent cement mix shown in Figures 9 and 10. The cement-catalyst binder that permits cold curing reduces the amount of cement required. The catalyst binder reportedly costs only 60 cents per 1,000 bricks, and the entire process produces bricks that are uniform in size and shape, facilitating future use of epoxy in place of mortar to hold bricks together. Preliminary indications are that this cement mix may be reduced to 6 percent or less, thus substantially reducing the cost of production. Tekology Corporation has recommended further quality testing and an operational pilot plan study. A copy of their recommendations is shown in Appendix A.

# RESERVE MINING COMPANY
## SILVER BAY, MINNESOTA

### TACONITE TAILINGS UTILIZED IN BRICK PRODUCTION

GREATER THAN 100 MESH
COBBER MAGNETIC SEPARATOR
LESS THAN 100 MESH
COBBER MAGNETIC SEPARATOR
FINE TAILINGS FROM
EFFLUENT LAUNDER

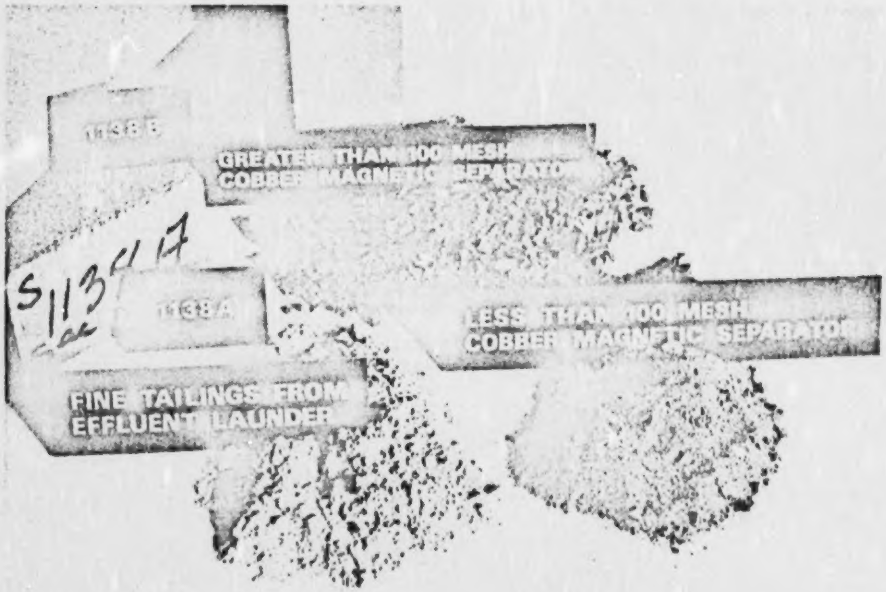
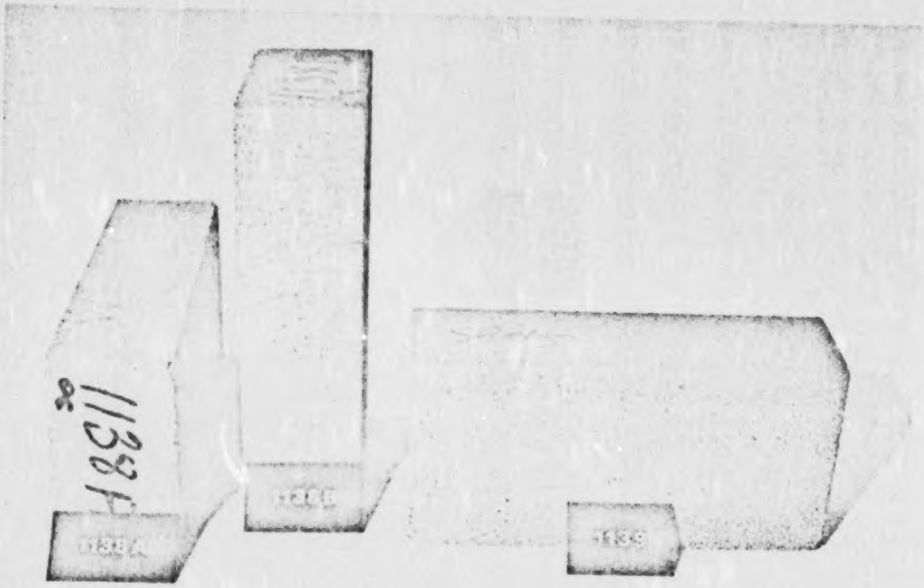

1138 B
GREATER THAN 100 MESH
COBBER MAGNETIC SEPARATOR
S113417
1138A
LESS THAN 100 MESH
COBBER MAGNETIC SEPARATOR
FINE TAILINGS FROM
EFFLUENT LAUNDER

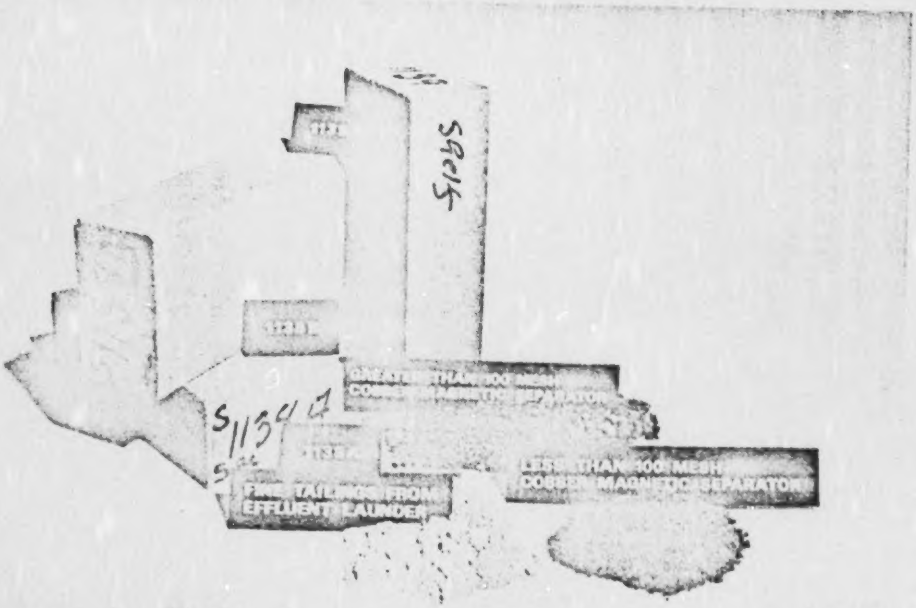
FIGURE 9

# RESERVE MINING COMPANY
## SILVER BAY, MINNESOTA

### BRICKS PRODUCED FROM TACONITE TAILINGS



1138A
1138A
1139



S1134
GREATER THAN 400 MESH
COBBER MAGNETIC SEPARATOR
LESS THAN 400 MESH
COBBER MAGNETIC SEPARATOR
FINE TAILINGS FROM
EFFLUENT LAUNDER

FIGURE 10

Table 16 indicates the typical production costs per thousand units using the standard brick sizes (7-5/8 in. x 3-5/8 in. x 2-1/3 in.). If aggregate at the site costs $2.50 per ton, the operating expenses are $10.75 per 1,000 units, and the other cement binder material costs are $10.00, the bricks would cost $20.75 per 1,000 bricks. In comparison, the market price for standard bricks in the Great Lakes area is $24.00 to $28.00 per thousand.

Table 16

Comparison of Costs of Taconite Bricks
made with Various Cement Mixes[1]

| Cement Content: | A - 10% | | | B - 6% | | C - 4% | |
|---|---|---|---|---|---|---|---|
| Cost of aggregate, $ per ton | 2.50 | 2.0 | 1.0 | 2.0 | 1.0 | 2.0 | 1.0 |
| Cost of raw materials | 10.00 | 9.10 | 7.14 | 7.45 | 5.35 | 6.62 | 4.45 |
| Operating Expenses | 10.75 | 10.75 | 10.75 | 10.75 | 10.75 | 10.75 | 10.75 |
| Cost of Product | 20.75 | 19.85 | 17.89 | 18.20 | 16.10 | 17.37 | 15.20 |

[1] If pigmentation is required - for face brick only - add $2.00 per 1,000 units.

A comparison of equivalent weights of concrete blocks and bricks made from taconite and those made from common materials is indicated below:

| | Common Material lbs. | Taconite lbs. |
|---|---|---|
| Block | 39 | 41 |
| Brick | 5 | 7.3 |

The above weights are based on blocks having a mixture of 90 percent tailings (specific gravity of 3.10) and 10 percent cement. The specific gravities of the more common blocks and bricks are 2.65 and 1.90, respectively.

The population of Standard Metropolitan Statistical Areas SMSA) for Minneapolis-St. Paul and for the Lower Great Lakes, which would be potential markets for these new bricks are shown below:

| Standard Metropolitan Statistical Area | Population |
|---|---|
| Minneapolis – St. Paul | 1,686,000 |
| Milwaukee | 1,419,000 |
| Chicago | 6,920,000 |
| Gary | 619,000 |
| Detroit | 4,220,000 |
| Cleveland | 2,065,000 |
| Buffalo | 1,350,000 |
| Toledo | 679,000 |
| Erie | 261,000 |
| Toronto | 800,000 |
| TOTAL | 20,019,000 |

Total building block sales in the United States in 1968-69 were estimated (by the American Concrete Institute) at approximately 3.2 billion blocks, and total brick sales in 1970 were estimated (by the Structural Clay Products Institute) at 7 billion bricks. Thus, if based on the market and population projection, sales of both of these products in the Great Lakes Region would be approximately 10 percent of the total domestic brick market. Based on these estimates, the equivalent weights of taconite utilization in the manufacture of block and bricks would be 6.55 and 2.55 million tons per year, respectively, or a maximum possible total tailings utilization of 9.10 million tons per year.

### Construction of a Recreational Skiing Area

The utilization of tailings in the construction of a ski area, or augmenting the slope of an existing hill to enhance its potential as a ski slope, was examined. This approach does not appear to hold to much promise by itself, but when considered with other possibilities may be attractive. A detailed discussion of this subject is included as Appendix B.

# SECTION V

# CONCEPT DESIGN

## Basis of Design

The concept design of tailings treatment and disposal alternatives considered by ROY F. WESTON to be the most feasible, both from the technical and cost standpoints, is based on the following factors:

1. Wastewater flow and solids estimates obtained from the operational analysis performed at the Silver Bay plant by ROY F. WESTON personnel. The results of this analysis are shown in Appendix C, along with the other taconite beneficiation operations visited by ROY F. WESTON personnel.

2. The results of treatability studies performed by ROY F. WESTON technical personnel at the Silver Bay plant.

3. The results of wastewater sampling and subsequent laboratory analyses performed by ROY F. WESTON personnel during the course of the study.

4. Review by ROY F. WESTON of past studies, engineering reports, and legal proceedings regarding the disposal of taconite tailings from Reserve Company's Silver Bay plant.

The alternatives to be evaluated differ only in the method of tailings disposal. Two basic approaches will be evaluated: one provides complete on-land disposal of separated tailings: the other provides for on-land disposal of the fines, with in-lake disposal and/or reuse of the coarse tailings.

The operational analysis performed at the Silver Bay plant established the average wastewater flow at 412,000 gpm and the average tailings discharge at 67,000 standard tons per day or 60,000 long tons per day (LTPD). The selected design flow (292,000 gpm) is based upon the elimination of 120,000 gpm of flushing water from the West Launder. This flushing water is required to transport the tailings through the launder to the discharge point at the end of the delta, and has no direct role in the beneficiation process. By intercepting the West Launder wastewater flow prior to the addition of this flushing water and by locating the on-site treatment process as close to this point as practicable, the requirement for the flushing water can be eliminated. The quantity of tailings produced by the plant would remain unchanged by such a flow reduction, and a tailings discharge rate of 65,000 LTPD was selected as the process design value.

A hydraulic separation of the fine and coarse solids would be the first step in the treatment system. An overflow rate of 9,300 gpd per sq.ft. would be required to remove coarse tailings (i.e. material retained on 150-mesh screen) from the wastewater stream. This separation step would also reduce the wear on subsequent mechanical equipment and minimize the load on sludge-collection mechanisms located in the thickeners.

Fine tailings (less than 150-mesh) would be removed from the wastewater using gravity settling and the addition of organic polyelectrolytes (polymers). Polymers would be fed to the Hydroseparator overflow at a dosage of 2.0 mg/l: rapid mixing and separate flocculators would be provided to promote flocculation. Treatability studies indicated that rapid flocculation is required to insure optimum flocculation; therefore, flocculator mechanisms should be variable-speed, capable of providing a flocculator tip speed of approximately 60 feet per minute.

Gravity thickeners would have an overflow rate of 3,000 gpd per sq.ft. to remove the flocculated fine tailings. Underflow solids would be removed from the thickeners at a concentration of 400,000 to 500,000 mg/l. Thickener underflow would be pumped to either a slurry holding tank prior to overland pumping, or to vacuum disc filters for dewatering. The disc filters would have a yield of 150 lbs/sq.ft./hr. and produce a filter cake with a moisture content of approximately 30 percent.

Overflow from the gravity thickeners would be recycled to the Silver Bay plant's water intake located near the northeast corner of the harbor. To minimize the buildup of suspended and dissolved solids in the recycled process water, approximately 8.5 percent of the thickener overflow would be removed from the system and replaced by fresh water from the harbor. The overflow removed from the cycle would be treated by chemical flocculation and settling. A design overflow rate of 1,000 gpd per sq.ft. was used to size these clarifiers. Treated overflow from the clarifiers would be discharged to Lake Superior through a sub-surface diffuser system This diffuser system should dilute the treated effluent by approximately 80:1, which should be sufficient to prevent the occurrence of local "green water". The underflow solids would be handled in the same manner as the fine tailings.

Where used, overland piping would contain a fine tailings slurry with a solids content between 40 and 50 percent. Minimum velocities in the pipeline would be between 8 and 9 fps, and the total head requirements for the transport pumps would be 1,300 feet.

Tailings dewatered to a moisture content of 30 percent can be hauled by rail. Bottom dump ore cars would be used to carry the tailings to the Lower Lax Lake disposal site. The ore cars would be heated and insulated. The tailings disposal train would be separate from the ore trains to assure continuity of operation.

On-land disposal would be at the Lower Lax Lake Site. The impoundment would not extend into the actual Lax Lake area, but remain mostly in the marshy valley to the south. Coarse tailings would be used for dam construction whenever possible, with rock fill to stabilize the toe. Excavation to bedrock is estimated to be an average of 10 feet. The impoundment face of the dam would be made impervious by using a compacted layer of suitable native earth.

The treatment approach utilized by ROY F. WESTON is conservative in comparison to most of the other approaches that have been considered. The WESTON approach will prevent the occurrence of "green water" and comply with specific standards of quality and purity for Lake Superior water after admixture of the treated effluent with Lake Superior water at the point of discharge.

### Discussion of Alternative Design Approaches

Five separate alternatives have been developed for the disposal of tailings from the Silver Bay plant. These alternatives all follow the same basic approach for on-site treatment.

with separation of the tailings into coarse and fine fractions. Each alternative differs, however, in its method of handling and disposing of these separated fractions:

Alternative No. 1 - Coarse and fine tailings are dewatered separately, then combined and transported by rail to the Lower Lax Lake area for disposal.

Alternative No. 2 - Coarse tailings are dewatered and rail hauled to the lower Lax Lake impoundment, while the fine tailings are pumped to the basin via overland pipeline.

Alternative No. 3 - Coarse tailings are dewatered and conveyed to the edge of the delta for in-lake disposal, and the fine tailings are dewatered and hauled by rail to the Lower Lax Lake area for on-land disposal.

Alternative No. 4 - Coarse tailings are dewatered and conveyed to the edge of the existing delta for in-lake disposal, while fine tailings are pumped overland to the lower Lax Lake area for on-land disposal.

Alternative No. 5 - Coarse tailings are washed with coarse screens then transported by pipeline to a submerged discharge point in Lake Superior. Fine tailings are pumped overland to the lower Lax Lake impoundment.

Three of the alternatives (Nos. 3, 4 and 5) deal with a combination of in-lake and on-land disposal, while the remaining Alternatives (Nos. 1 and 2) propose total on-land disposal. A cost comparison for all the alternatives is presented in Table 17. Complete technical descriptions of all the alternatives, with corresponding plot plan, process flow descriptions, and cost estimates, are provided in Appendix D.

The alternatives that provide for in-lake disposal concern the direct discharge only of the coarse tailings (greater than 150 mesh) to the lake. The fines, which have been related to the formation of green water and have the maximum potential for leaching metals and other contaminants to the lake, would be removed before the coarse tailings are discharged. The dewatering screens for Hydroseparator underflow permit the fines (less than 150 mesh) to be washed out of the coarse tailings and returned to the treatment process.

In all the alternatives presented, the fine tailings would be discharged to the Lower Lax Lake Disposal Area. This site was chosen for its size and proximity to the Silver Bay plant. It offers a long-term solution to the tailings disposal problem while several of the other areas previously proposed as potential on-land disposal sites offered significantly shorter operational life.

The development of the disposal area would create an impoundment requiring six earthen-type dams. The dams (shown in Map 2) would be constructed to a final elevation of 1,300 feet. In addition to the impoundment dams, two diversion dams, three diversion channels, and an outlet channel are proposed. Diversions F and G would divert the Beaver River and Big Thirtynine Creek from the impoundment area. With the construction of Dam E at the northern end of the tailings basin, runoff from the diverted Beaver River and Fortythree Creek would back up and eventually flood the Lax Lake area. To eliminate this problem, outlet tunnels would be constructed at location H to provide a means of discharge.

## Table 17

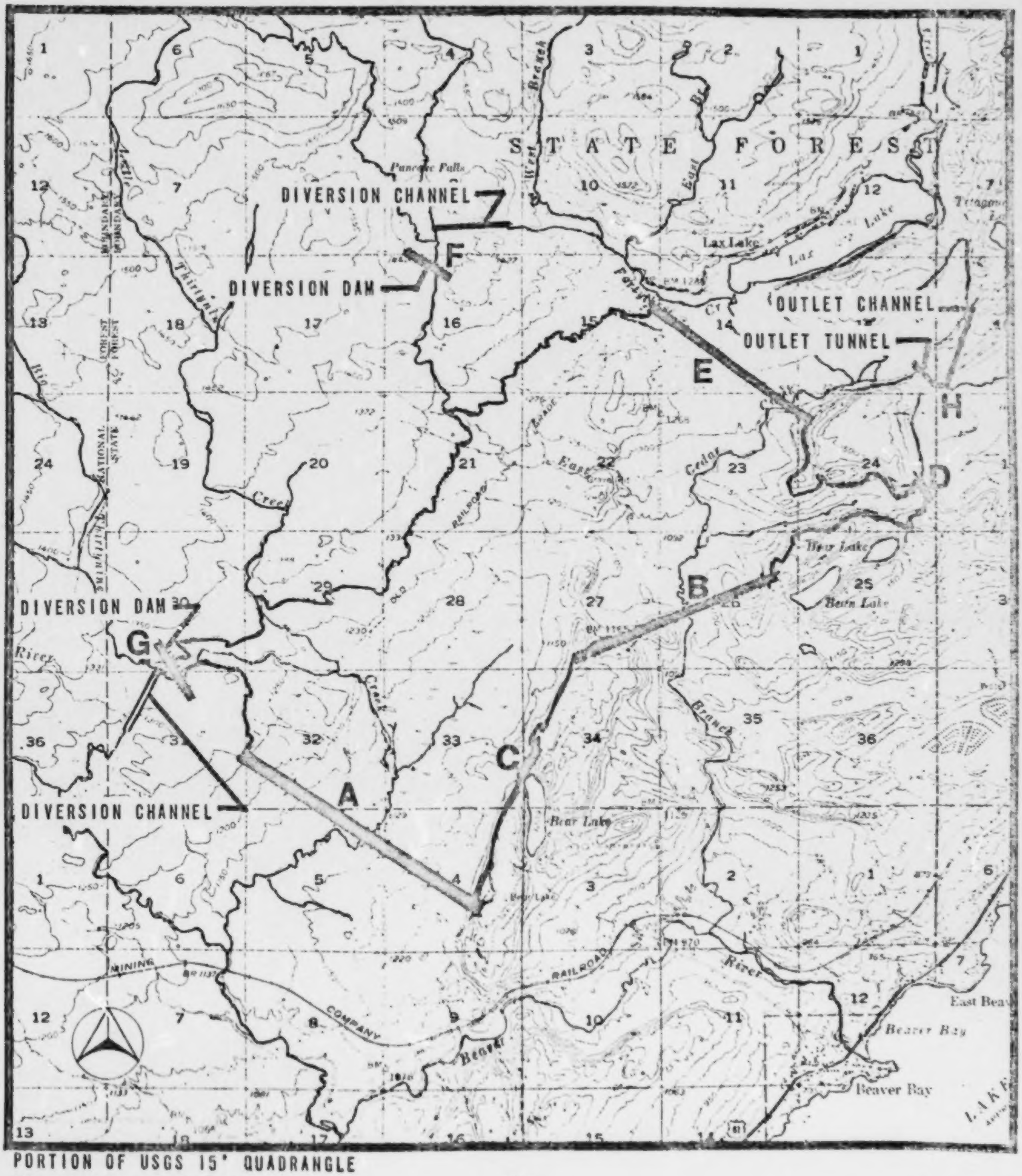
### Cost Comparison of Disposal Alternatives

| | Alternative No. 1 | Alternative No. 2 | Alternative No. 3 | Alternative No. 4 | Alternative No. 5 |
|---|---|---|---|---|---|
| | | | ESTIMATED CAPITAL COST (1971) | | |
| On-Site Processing | $20,632,000 | $19,441,000 | $20,632,000 | $19,441,000 | $19,441,000 |
| Water Treatment | 1,517,000 | 1,517,000 | 1,517,000 | 1,517,000 | 1,517,000 |
| Tailings Transport | 25,991,000 | 26,609,000 | 22,481,000 | 3,953,000 | 4,119,000 |
| Disposal Site | 17,017,000 | 17,017,000 | 17,017,000 | 17,017,000 | 17,017,000 |
| Sub-Total | $65,157,000 | $64,584,000 | $61,647,000 | $41,828,000 | $42,094,000 |
| Contingency at 15% | 9,774,000 | 9,688,000 | 9,247,000 | 6,274,000 | 6,314,000 |
| Total | $74,931,000 | $74,272,000 | $70,894,000 | $48,102,000 | $48,408,000 |
| | | | ESTIMATED ANNUAL COSTS (1971) | | |
| Operating Costs | $ 7,229,000 | $ 7,375,000 | $ 6,844,000 | $ 5,731,000 | $ 5,981,000 |
| Fixed Costs | | | | | |
| Depreciation | 3,746,000 | 3,713,000 | 3,545,000 | 2,405,000 | 2,420,000 |
| Interest | 3,371,000 | 3,342,000 | 3,191,000 | 2,165,000 | 1,972,000 |
| Total | $14,346,000 | $14,430,000 | $13,580,000 | $10,301,000 | $10,373,000 |

[1] Land costs not included.

# RESERVE MINING COMPANY
## SILVER BAY, MINNESOTA

### PROPOSED LOWER LAX LAKE IMPOUNDMENT BASIN


STATE FOREST
DIVERSION CHANNEL
F
DIVERSION DAM
Lax Lake
OUTLET CHANNEL
OUTLET TUNNEL
E
H
D
B
Bear Lake
DIVERSION DAM
G
C
A
DIVERSION CHANNEL
Bear Lake
RAILROAD
MINING COMPANY
River
Beaver Bay
East Beaver Bay
LAKE

PORTION OF USGS 15' QUADRANGLE
SILVER BAY, MINNESOTA
SCALE: 1" = 1 MILE

MAP 2

The total cost for construction of these facilities at the disposal site has been estimated at $88,317,000 plus contingency costs, by Justin and Courtney. It would be misleading to present this as a direct capital cost for any alternative, however, because dam construction would be a continuous operation throughout the life of the disposal system. Disposal site costs have therefore been divided up into a capital cost for initial dam construction and an annual operating cost to cover the continual build-up of the dam to the final elevation of 1,300 feet.

The initial dam construction would include a starter dam at location A and the diversion structures required to control runoff in the area of the impoundment. These facilities would require a capital investment of $17,017,000 and make up the disposal site costs presented in Table 17. The remaining costs for dam construction ($71,300,000) are included in the annual cost estimates under "operation" and represent a yearly cost of $1,783,000.

The approach used to establish the annual cost for dam construction was based upon the straight-line depreciation of the required capital investment for dams for the next 20 years. (Twenty years was chosen because it represents the design life of all the other facilities included in the alternatives.) Because the remaining capital investment of $71,300,000 would result in dams providing a 40-year storage capacity, it was assumed that only half of that investment ($35,650,000) would be required over the next 20 years, and it is upon this basis that the annual cost for dam construction has been approximated.

Overland pumping proved to be the least expensive method of transporting the fine tailings to the disposal area. Rail haul of fines would require almost $20,000,000 more in capital investment because of increased equipment requirements. It should be noted, however, that for total on-land disposal, rail haul of both coarse and fine tailings proved slightly cheaper than the rail haul of coarse material and the pumping of the fines. This appears to indicate that after the initial investment for rail haul is made, the incremental cost for increasing the rail hauling capacity is relatively small.

Total rail haul of dewatered tailings is presented in Alternative No. 1. The tailings would be deposited at the disposal site in a relatively dry state, thus reducing the volume of water necessary to be impounded. Surface runoff, however, would tend to wash out the fines which must be prevented from eventually finding their way to Lake Superior.

The dams for the impoundment area would be constructed with coarse tailings wherever possible. These tailings should form a stable dam material if a rock fill toe and gentle slopes are employed. For those alternatives which do not propose rail haul, the coarse tailings would have to be hauled to the dam sites by truck. Separation of coarse and fine tailings at the on-site treatment plant facilitates this utilization of the tailings. Further utilization of certain portions of the tailings for the fabrication of building blocks or for use as construction sand and gravel is also made possible by this separation.

A capital cost comparison reveals that the combination of in-lake and on-land disposal results in a significantly lower capital investment than total on-land disposal. Alternative No. 4 is apparently the least-cost alternative, showing a savings of more than $25,000,000 over the total on-land disposal alternatives (1 and 2). Alternative No. 5 is approximately $300,000 more expensive than Alternative No. 4 in terms of capital cost. The high maintenance and operating costs associated with piping the coarse tailings slurry to a depth of 150 feet in Lake Superior is the primary cause for the more than $70,000 difference in total annual costs that would accrue over the life of these alternatives.

A comparison of Alternatives 1 and 2 indicates that the rail haul of all tailings is estimated to be slightly less costly than the rail haul of coarse tailings and the piping of fines. Furthermore, the capital cost of Alternative No. 3, which deals with rail haul of fines and the discharge of coarse to the lake, appears to be about $3,400,000 less than the capital cost of total on-land disposal.

Although in-plant alterations have not been presented as a part of any of the alternatives, there is evidence that significant cost savings may be available using this approach. One scheme for in-plant recycling of process water is expected to reduce the total plant wastewater flow by approximately 60,000 gpm This scheme involves the recycling of Hydroseparator overflow to the Rougher Magnetic Separator and recycling of Finishing Magnetic Separator wash water to the Rod Mill. If additional recycling techniques were adopted, additional significant flow reductions may be effected.

In-plant alterations concerning tailings control and handling could also be implemented and might provide further significant reductions to the on-site processing plant. These alterations involve the removal of coarse tailings from the Magnetic Cobber sump. Comparison of the results of sieve analyses of Cobber tailings with total plant tailings reveals that approximately 50 percent of the total plant tailings can be removed after passing through the Cobber Magnetic Separators. This action would eliminate a major portion of the flushing water that must be added to the launders simply to transport the tailings. If the larger particles are removed, however, the need for this flushing water is greatly reduced. The direct cost reduction that could be gained through this approach is difficult to predict. Restrictive conditions in the Concentrator Plant may make the location and construction of these facilities expensive. Preliminary investigations have revealed, however, that in-plant alterations could offer substantial savings in the capital cost of treatment. The magnitude of such savings can be determined only after a detailed engineering evaluation.

## Environmental Impact of Tailings Discharge

### Proposed Degree of Treatment

The Silver Bay plant is currently releasing without treatment 60,000 LTPD of tailings in an average wastewater flow of 412,000 gpm. The five alternatives proposed for treatment of this wastewater provide identical on-site processing facilities, which have the capability of eliminating a major portion of the solids and water discharge. Table 18 below provides a comparison between the existing discharge and the proposed discharges and demonstrates the degree of treatment expected.

Table 18

Existing and Proposed Tailings Discharges

| | Solids Discharged to the Lake LTPD | Wastewater Flow gpm | Reduction of Solids percent |
|---|---|---|---|
| Existing | 60,000 | 412,000 | 0 |
| Alternative 1 | <2.5[1] | 25,000 | 99.9+ |
| Alternative 2 | <2.5[1] | 25,000 | 99.9+ |
| Alternative 3 | 37,830[2] | 25,000 | 37 |
| Alternative 4 | 37,830[2] | 25,000 | 37 |
| Alternative 5 | 37,830[2] | 46,000[3] | 37 |

[1] Water treatment plant effluent suspended solids at 20 mg/l.

[2] Assumes no utilization or reuse of coarse tailings. However, projections on utilization and reuse of coarse tailing could reduce discharge to 5,200 LTPD or approximately 91 percent reduction of solids.

[3] Includes fresh water to resuspend coarse tailings.

The flow reduction proposed in the five treatment alternatives results from the recycle of treated thickener effluent to the plant's water intake. A blowdown stream of 25,000 gpm is proposed to prevent the excessive buildup of suspended and dissolved solids in the process water. Buildup of dissolved solids (especially chlorides and silica) could be detrimental to the formation of the iron pellets and could reduce the quality of the final product. Fresh water from the harbor would replace that portion of the process water which is drawn off. Process water removed from the system would be treated in the water treatment plant prior to discharge.

Preliminary research by Reserve Mining has revealed the increase in process water solids that can be expected from a closed-circuit water system These data (reported in a memo from R. S. Lemire to K. M. Haley dated January 28, 1971) reflect the buildup of solids after fifteen recycles. The laboratory studies were performed during winter conditions at the Silver Bay plant and therefore also provide information concerning the buildup of calcium chloride.

Heavy metals generally showed no significant increases in concentration with recycling, but increases of 50 to 100 percent were evident for calcium magnesium sodium potassium, and alkalinity. Nitrogen increases were observed and are attributed to residuals within the ore. Chloride showed a ten-fold increase from its initial concentration, but appeared to reach an equilibrium concentration after thirteen cycles. Total dissolved solids showed a two-fold increase and appeared to reach equilibrium by the eleventh cycle.

The blowdown stream would be treated before discharge to the Lake to reduce the concentrations of most contaminants to the lowest practicable levels. Although specific dissolved contaminants may be present in the treated effluent at concentrations higher than those currently observed in the wastewater effluent, the total amount (in pounds) of such contaminants in the discharge should be only a fraction of the total from once-through wastewater discharge.

Treatment of the effluent (blowdown stream) can be accomplished using chemical coagulation and gravity settling to remove suspended solids. If required, soluble metals and phosphates can be removed by selecting the proper chemical and dosage for precipitation. Thus, it is possible to produce an effluent acceptable for discharge. It should be noted, however, that the actual effluent quality that can be obtained from the water treatment plant can best be verified through laboratory and small scale pilot-plant studies. Such studies should include research on a closed-circuit pilot-plant process water system.

The treatment provided for Alternatives 1 and 2 will remove more than 99.9 percent of the suspended solids. These alternatives propose the complete on-land disposal of tailings. The only tailings solids which could reach Lake Superior would be contained in the effluent of the water treatment plant, estimated to be approximately 20 mg/l or less of suspended solids, or 2.5 TPD or less. This is equivalent to approximately 1.0 mg/l suspended solids or less at current discharge rates.

Alternatives 3, 4, and 5 each involve a combination of in-lake disposal and on-land disposal. With the discharge of coarse tailings to the Lake the percent reduction in solids is about 37 percent. In Alternatives 3 and 4, the coarse tailings should be placed on the delta in a relatively dry form, and then pushed to the water's edge, thus providing no increase in the total flow discharged to the Lake. Alternative 5, however, provides for the reslurrying and pumping of the coarse tailings to a discharge point approximately 150 feet below the surface of the Lake, and thus increases the total discharge flow to 46,000 gpm.

The utilization of coarse tailings as a building material would greatly reduce the amount of coarse tailings discharged to Lake Superior. Table 19 reveals the average yearly tonnage of +150 mesh tailings that is produced at the Silver Bay plant and the potential markets that exist for this material.

Table 19

Coarse Tailings[1] Production and Utilization

| | Tons/year |
|---|---|
| Production | 15,100,000 |
| Utilization | |
| Dam Construction (yearly average over 40 years) | 2,700,000 |
| Sand and Aggregate[2] | 1,200,000 |
| Building Blocks | 6,550,000 |
| Brick Making | 2,550,000 |
| Sub-Total | 13,000,000 |
| Remaining Coarse Tailings for Lake Disposal | 2,100,000 |

[1] Coarse Tailings are those larger than 150 mesh.
[2] Based on findings of Arthur D. Little, Inc. report (Proposal No. 19).

These figures indicate a potential for the utilization of all but 2,100,000 tons of the coarse tailings. Even if this 2.1 million tons of material were to be discharged to Lake Superior, this approach still offers a substantial reduction from the estimated 24.5 million standard tons that are presently being discharged. The resulting overall reduction in solids, due to on-land disposal of the fines and the utilization of coarse tailings, would be approximately 92 percent.

### Impact of In-Lake Disposal of Tailings

The release of tailings to the waters of Lake Superior represents the discharge of a conservative type of pollution. The tailings do not promote an aggressive decay in the quality of the Lake environment but possess the potential for leaching their entrapped inorganic and metallic constituents into the Lake. The leaching and dissolution of the tailings, therefore, may represent a long-term influence upon the Lake Superior ecosystem.

Leaching from the tailings can be described as the dissolution of chemical constituents from the surface of the individual particles. Because leaching occurs at the surface, the degree of leaching is directly dependent on the amount of particle surface area available. Those particles which represent the major portion of the total surface area will therefore provide the greatest potential for leaching. An analysis was performed to relate the distribution of particle sizes with the distribution of the corresponding surface areas. This provided the basis for an assessment of the portion of the tailings which provided the greatest potential for leaching.

The surface area analysis for tailings was performed utilizing information supplied by the Reserve Mining Company as basic design data. The absolute specific gravity of these tailings is 3.1, and the dry bulk density of the total tailings is 132 lbs./cu.ft. No density or unit volumes of specific particles are available, and the dry bulk density is thus used as an average density for all sizes.

The screen size analysis of tailings used was taken from Table 5, Appellant's Exhibit 106, District Court files, Lake County Minnesota October 2, 1970. The information obtained from this table is presented as part of Table 20 of this report.

The cumulative surface areas calculated in Table 20 indicate that the smaller particle sizes contribute the major portion of the total surface area available for leaching. Approximately 90.6 percent of the total surface area of the tailings is concentrated in particles 325 mesh or smaller. These particles however, constitute only 38.6 percent of the weight of the total tailings. At the 150 mesh separation that is proposed in alternatives 1 through 5 of this report, the final fraction (<150 mesh) represents approximately 97 percent of the total tailings surface area. This fine fraction represents approximately 52.4 percent of the weight of the total daily tailings produced.

The surface area of the particles most likely is larger than indicated in Table 20, since the particles probably have more flat planes than spherical shapes. The assumption of spherical shapes and exposed area was made as the best approximation. The distribution of area could thus be skewed slightly toward the larger sizes if these sizes are representative of the more elongated shapes.

The analysis further indicates that particles in the clay size range (5 microns and smaller) constitute 6.5 percent of total tailings by weight and contribute about 36 percent of the total surface area. Silt-sized particles, (5-60 microns) are approximately 42 percent by weight and contribute about 60 percent of the surface area. By removing these and the clay-sized particles from the waste stream 96 percent of the surface area that could possibly continue leaching would be removed.

The Soil Conservation Service presented testimony at the second session of the Lake Superior Conference April 29-30, 1970 to the effect that the natural sediment delivered to Lake Superior in the United States (approximately half the Lake's Shoreline) was estimated to be 184,000 tons/year. This is approximately three times Reserve Mining's daily discharge or 0.9 percent of Reserve Mining's annual discharge. The sediment surface area discharged annually by rivers is estimated to be approximately equal to 6 days of Reserve Mining's discharge, or about 2 percent of the annual discharge.

By removing the particles that contribute approximately 96 percent of the surface area, Reserve Mining could reduce the potential leaching to approximately 2.5 times that contributed by natural sediments (down from 50 times the natural sediments). If 98 percent of the surface area is removed, the potential leaching could be reduced to 1.2 times that contributed by natural sediments.

It should be noted that these estimates are based on assumptions, because no size distribution of natural sediments has been determined. Thus, they cannot be relied upon to give more than a rough estimate of the potential reduction in surface area to be achieved.

An overall reduction of 96 to 98 percent of the total surface area of the tailings would have a marked effect on reducing the impact of tailings disposal in Lake Superior. Thus,

# Table 20

## Tailings Surface Area Discharged Per Day
## Distribution by Particle-Size Range

| Through/On | Average Particle Size[1] microns | Total Weight tons/day | Average Percent (by Wt.) | Dry Volume cu.ft./day | Unit Surface Area sq.ft./cu.ft. | Total Surface Area sq.ft./day | Percent of Surface Area in Size Range | Cumulative Surface Area Distribution |
|---|---|---|---|---|---|---|---|---|
| MICRON SIZES | | | | | | | | |
| 5/ | | 4,350 | 6.5 | 66,000 | $1.84 \times 10^5$ | $1.21 \times 10^{10}$ | 35.84 | 35.84 |
| 10/5 | 7 | 3,420 | 5.1 | 52,000 | $1.38 \times 10^5$ | $7.15 \times 10^9$ | 21.18 | 57.02 |
| 20/10 | 15 | 7,400 | 11.1 | 113,000 | $6.25 \times 10^4$ | $7.05 \times 10^9$ | 20.88 | 77.90 |
| 44*/20 | 32 | 10,600 | 15.9 | 144,000 | $3.0 \times 10^4$ | $4.30 \times 10^9$ | 12.73 | 90.63 |
| MESH SIZES | | | | | | | | |
| 270/325 | 48 | 3,140 | 4.7 | 47,500 | $2.08 \times 10^4$ | $9.85 \times 10^8$ | 2.92 | 93.55 |
| 200/270 | 64 | 3,350 | 5.0 | 51,000 | $1.58 \times 10^4$ | $8.05 \times 10^8$ | 2.39 | 95.94 |
| 150/200 | 90 | 2,750 | 4.1 | 41,800 | $1.06 \times 10^4$ | $4.42 \times 10^8$ | 1.31 | 97.25 |
| 100/150 | 125 | 3,000 | 4.5 | 45,500 | $7.7 \times 10^3$ | $3.50 \times 10^8$ | 1.04 | 98.29 |
| 65/100 | 177 | 2,130 | 3.2 | 32,500 | $5.45 \times 10^3$ | $1.77 \times 10^8$ | .52 | 98.81 |
| 48/65 | 250 | 1,670 | 2.5 | 25,500 | $3.80 \times 10^3$ | $9.7 \times 10^7$ | .29 | 99.10 |
| 35/48 | 355 | 1,670 | 2.5 | 25,500 | $2.82 \times 10^3$ | $7.2 \times 10^7$ | .21 | 99.31 |
| 28/35 | 500 | 2,000 | 3.0 | 30,300 | $1.80 \times 10^3$ | $5.44 \times 10^7$ | .16 | 99.47 |
| 20/28 | 610 | 2,270 | 3.4 | 34,500 | $1.04 \times 10^3$ | $3.59 \times 10^7$ | .11 | 99.58 |
| 14/20 | 1,000 | 2,950 | 4.4 | 44,700 | $8.9 \times 10^2$ | $3.98 \times 10^7$ | .12 | 99.70 |
| 10/14 | 1,408 | 3,550 | 5.3 | 50,800 | $6.8 \times 10^2$ | $3.47 \times 10^7$ | .10 | 99.80 |
| 8/10 | 1,900 | 4,400 | 6.6 | 67,000 | $5.0 \times 10^2$ | $3.47 \times 10^7$ | .10 | 99.90 |
| 6/8 | 2,850 | 4,100 | 6.1 | 62,300 | $3.2 \times 10^2$ | $1.99 \times 10^7$ | .06 | 99.96 |
| 4/6 | 4,000 | 2,750 | 4.1 | 41,800 | $2.5 \times 10^2$ | $1.04 \times 10^7$ | .03 | 99.99 |
| 3/4 | 5,000 | 1,230 | 1.8 | 18,600 | $1.9 \times 10^2$ | $3.54 \times 10^6$ | .01 | 100.00 |
| **Total** | | 66,730 | | | | $337.6 \times 10^8$ | | |

| | |
|---|---|
| Average Tailings Density | 132 lbs/cu.ft. |
| Average Tailings Volume | 15.2 cu.ft./ton |

*325 mesh

[1] Sizes assumed to be median values between the "through" screen and "on" screen sizes.

an approximately 42 percent reduction in solids discharge to the Lake could result in a 96 to 98 percent reduction in impact on the Lake. This reduction in surface area can be achieved by eliminating the <150 mesh tailings from the tailings discharge.

An additional reduction in the surface area of the tailings discharged to Lake Superior can be achieved by the reduction of the amount of coarse tailings (larger than 150 mesh) discharged. This reduction will occur if the coarse tailings are utilized for dam construction, brick and block making, or on-land disposal. The reduction in surface area of tailings discharged daily from the plant will not eliminate the existing leaching potential that may be occuring from the past discharges, but it will serve to prevent a significant increase.

### Impact of On-Land Disposal of Tailings

The land areas under consideration for storage of tailings are located: 1) northwest of Babbitt in the vicinity of the Reserve Mine; 2) in the vicinity of mile-post 32 along the Reserve rail line; and 3) north of Silver Bay just west of Lax Lake. If land disposal of tailings is undertaken at one of these areas, the general physical appearance and present topography would be changed appreciably. Present terrain would be covered by a smooth plateau varying in thickness from a few feet to 100 feet.

The characteristics of the taconite tailings generated are such that the size of the particles deposited on land is the major factor in determining any environmental impact they might have in the vicinity of the disposal site.

Gravel and sand portions of the tailings, in the 3/8" to 100-mesh and greater size range, are similar to sands and gravels found elsewhere, although their compressive strengths are considerably greater. No appreciable leaching, or solubility, is expected from this size range, which constitutes roughly one-half of the tailings generated. Fine sand in the smaller than 100-mesh range, silts from 2 mm to 1/16 mm, and clay particles of 4 microns or smaller have some leaching potential.

The dusting problem associated with dry disposal or eventual drying of fine particulate matter can be overcome by application of a liquid encrustating agent. This material, if left undisturbed, will form an inert crust on the surface of taconite tailings and will minimize dusting until a soil cover can be placed on freshly deposited tailings. It has been shown at Reserve Mining, at Erie, and at other operations that with the addition of soil nutrients, vegetation can be grown readily on tailings disposal areas. Other solutions include storing the fines in a basin that would provide a water cover until it can be dredged for dikes, which could then be planted with suitable vegetation.

In depositing the extremely fine particles, every effort should be made to prohibit their entrance into a stream and to prohibit the extensive leaching of soluble elements into stream beds.

An advisable course of action prior to disposal on-site would be the construction of impervious dikes to control the seepage of any leachate.

Another form of treatment and clarification would be the construction of dikes of tailings material, which would act as filters. By controlling the formation of a filter cake of fine tailings on the dike face, a clear and satisfactory water can be obtained at the opposite dike face for discharge to a stream or back to the plant.

A surveillance program should be instituted and continued concurrently with on-land disposal to determine if any stream quality changes or other detectable effects are taking place.

The area west of Lax Lake and north of Silver Bay offers approximately 9 square miles of deposit area in close proximity to the Reserve beneficiating plant. Lax Lake can be isolated from the impoundment area by an additional embankment at the northeast end of the impoundment, and by diversion of Lax Lake drainage streams. The natural drainage flowing into the impoundment area can be reduced by diverting the Beaver River above the impoundment into Fortythree Creek and also by diverting Big Thirtynine Creek into the Beaver River at a point below the impoundment. The impact on the deposit area and the need for treatment of impoundment water can thus be minimized, and the water quality of the natural streams can be assured. The cost estimates shown in Table 17 are based on minimizing the impact on Lax Lake as described above.

In the future, when the tailings basin is complete, the area can be reclaimed and vegetation grown on the surface. The general topography of the area will have been changed from a marshy, swamp area to a relatively level plateau. Therefore, the environmental impact on this area appears to be minimal especially when compared to the impact on the land near Babbitt.

# SECTION VI

# ECONOMIC AND FINANCIAL ANALYSIS

## Reserve Mining Profile

Armco Steel and Republic Steel Corporations, the parent companies of the Reserve Mining Company, are among the top five in the steel industry. Their ranking in raw steel production is currently fourth and third, respectively, and their current combined production is approximately 13 to 15 percent of the industry total. The corporations are sole owners of Reserve Mining Company and share equally in all costs of operation, all debts, and all capital outlays. Production of beneficiated pellets is determined jointly by Armco and Republic, and shipments are also shared equally. A summary of the annual operating records for Armco and Republic for 1968, 1969, and 1970 is shown in Table 21.

Table 21

Annual Operating Records of Armco Steel and Republic Steel

| | | Raw Steel Produced (Net Tons) | Shipments (Net Tons) | Operating Profit | Net Income | Net Income as Percent of Investment |
|---|---|---|---|---|---|---|
| 1970 | Armco | 7,908,000 | 5,442,000 | $157,012,000 | $56,153,000 | 5.6 |
| | Republic | 9,638,450 | 6,654,203 | 111,120,340 | 35,163,538 | 4.3 |
| 1969 | Armco | 8,421,000 | 5,479,000 | 213,095,000 | 95,153,000 | 8.4 |
| | Republic | 10,742,307 | 7,354,245 | 205,927,131 | 79,087,073 | 7.1 |
| 1968 | Armco | 7,700,000 | 5,506,000 | 227,356,000 | 95,040,000 | 8.8 |
| | Republic | 9,748,688 | 7,072,000 | 192,446,607 | 78,153,079 | 7.2 |

Source: Iron Age

Reserve Mining Company thus operates as a division or "cost company" of Armco and Republic, and all operating costs are paid by the parent companies and deducted on their income tax returns. Depletion allowances are also claimed by the parent companies, under the Department of Revenue Ruling 56-542. Any funds provided by the parent companies for operation of the cost company are recoverable from merchantable ore or, if not used in mining operations, are returned. Armco and Republic may sell all or a part of their contractual interest with a sale of all or part of their stock. The new party would then assume the obligations mentioned previously.

In September 1951, Armco Steel and Republic Steel Corporations announced their plan to construct a plant of 3,750,000 tons initial capacity, with a projected initial construction cost of $185,000,000. Armco and Republic contributed ten percent, or $18.5 million, with the remainder being financed by 25-year, four-percent mortgage bonds guaranteed by the two parties.

In the first full year of operation (1956), Reserve Mining produced approximately 3.7 million tons of pellets. With process modifications, the plant was producing approximately 6 million tons per year by 1961. After large-scale blast furnace tests in 1960 indicated the prospects of improved operation with a pellet charge, a 3-million ton per year, $120,000,000 expansion of the Reserve operation was announced. Production capacity has increased again since 1967, and currently is between 11 and 12 million tons per year. Through the parent companies, Reserve Mining entered into agreements on December 15, 1952 and December 9, 1960 with nine insurance firms to issue Mortgage Bonds of Series A and Series B. Armco and Republic are responsible for the retirement of these debts. The total investment is currently $350,000,000.

The operating costs vary depending on the iron content of ores mined, transportation and handling requirements, labor costs, power used, etc. The estimates of Reserve Mining's 1970 revenue, costs, and net profit (presented in Table 22) were based on research conducted by the Stanford Research Institute, the University of Minnesota School of Mines, and Reserve Mining's exhibits from the 1969 Lake County (Minnesota) District Court trial. The published market value shown in this table is taken from the Skillings Mining Review, as are transportation and handling costs.

The beneficiated pellets produced at Reserve are shipped to Armco and Republic blast furnaces in the Great Lakes Region as indicated in Table 23. Each company currently receives approximately 5.3 million tons of pellets per year (approximately 3.3 million tons of iron as Fe). This was approximately 60 percent of Armco's ferrous input and 50 percent of Republic's for 1970. The balance of the ferrous input for both companies comes from scrap purchases and from other ore fields, as indicated in Table 24.

## General Comparison of Costs at Various Mining Companies

Comparison of costs between one taconite plant and another depends on the availability of cost figures from companies of similar output and similar operating procedures. Since operating costs are considered proprietary information and thus are closely guarded, and since the operating costs vary widely with changes in such component operations as stripping, mining, etc., a detailed comparison is not possible without detailed cost disclosures by the companies involved. However, a general comparison of operating costs based on available estimated figures provides some measure of inter-company differences. In the ensuing discussion, the principal information source is a 1970 Stanford Research Institute report to the Paulucci Foundation.

A starting point for cost comparison is the price of pellets at the point of shipment. Reserve Mining's pellet price has been estimated at $12.27/ton and Erie's pellet price at approximately $12.64/ton. Estimates for other taconite mining companies range from $12.13 to $12.65 per ton.

Erie's transportation costs are lower than Reserve Mining's, despite Erie's longer mine-to-harbor shipping distance (75 miles vs 45 miles). One major factor is that Erie ships finished pellets, with a volume about one-third that of Reserve Mining's shipments of crude ore. The unit shipping costs at Reserve Mining thus are $0.35 to $0.40 per ton of pellets, compared to Erie's $0.20 to $0.25. The other taconite operations, which are smaller, have contracts with public railroads (common carriers), and their costs are about $1.25 per ton of pellets.

## Table 22

## Estimates of Revenue, Costs and Net Profit per Ton of Pellets Produced by Reserve Mining

| | Dollars per Ton | |
|---|---|---|
| Revenue | | |
| Market Value per Ton of Pellets Delivered to Lake Erie Ports (Based on 61 percent Iron Content at $0.252 per Iron Unit) | | 15.36 |
| Costs | | |
| Mining Costs | | |
| Mine Stripping and Development | .18 | |
| Mining, Processing and Handling at Mine Site | 2.00 | |
| Transportation and Handling to Silver Bay Plant | .40 | |
| Ore Processing Costs | | |
| Crushing | .50 | |
| Concentrating | 1.50 | |
| Pelletizing | 2.00 | |
| Sub-total | 6.58 | |
| Administration and Other Costs | | |
| General Expenses and Management | .75 | |
| Royalties | .19 | |
| Mesabi Trust | 1.00 | |
| State and Local Tax | .44 | |
| Depreciation and Depletion | 1.30 | |
| Sub-total | 3.68 | |
| TOTAL PRODUCTION COSTS | 10.26 | |
| Miscellaneous Costs (Town site and Mine Development) | .81 | |
| TOTAL COSTS INCURRED AT SILVER BAY | 11.07 | |
| Transportation and Handling Costs to Lake Erie | | |
| Freight Charges | 1.90 | |
| Dock Charges (Vessel to Rail) | .28 | |
| Sub-total | 2.18 | |
| COST DELIVERED AT LAKE ERIE | | 13.25 |
| Profit | | |
| Profit Before Federal Income Tax | | 2.11 |
| Estimated Federal Income Tax (Based on Taxes for 1967 to 1969) | | .66 |
| NET PROFIT PER TON OF PELLETS PRODUCED | | $1.45 |

## Table 23

## Great Lakes Region
## Locations of Armco and Republic Blast Furnaces

| Parent Company | Location | No. of Blast Furnaces | Types of Furnace Charge |
|---|---|---|---|
| Armco Steel | Ashland, Kentucky | 3 | Taconite Pellets and Natural Ore |
| | Hamilton, Ohio | 2 | Taconite Pellets and Natural Ore |
| | Middletown, Ohio | 1 | Taconite Pellets and Natural Ore |
| Republic Steel | Youngstown, Ohio | 4 | Taconite Pellets, Sinter, and Domestic and Foreign Ores |
| | Cleveland, Ohio | 6 | Taconite Pellets, Sinter, and Domestic and Foreign Ores |
| | Buffalo, New York | 2 | Taconite Pellets, Sinter, and Domestic and Foreign Ores |
| | Warren, Ohio | 1 | Taconite Pellets, Sinter, and Domestic and Foreign Ores |
| | Massillon, Ohio | 1 | Pellets and Ore |
| | Canton, Ohio | 1 | Pellets and Ore |
| | South Chicago, Illinois | 1 | Pellets, Sinter, and Lake Ores |

Source: American Iron and Steel Institute and Iron Age.

## Table 24

### Breakdown of Ore Received by Parent Companies from Various Ore Sources

| | Received Tons/Year | Percent of Mine Output |
|---|---|---|
| Armco Steel Corp. | | |
| Reserve Mining Co. | 5,300,000 | 50 |
| Newfoundland, Carol Pellet Co. | 772,000 | 7.7 |
| Knob Lake, Quebec, Division Iron Ore Co. of Canada | 510,000 | 5.1 |
| Rusk, Texas[1] | -- | – |
| | 6,582,000+ | |
| Republic Steel Corp. | | |
| Reserve Mining Co. | 5,300,000 | 50 |
| Michigan, Pioneer Pellet Plant | 210,000 | 17 |
| Newfoundland, Carol Pellet Co. | 772,000 | 7.7 |
| Bomi Hills, Liberian Mining Co.[2] | 800,000 | 40.0 |
| Knob Lake, Quebec, Division Iron Ore Co. of Canada | 510,000 | 5.1 |
| Mineville, New York[1] | -- | – |
| | 7,592,000+ | |

[1] Information not available.
[2] Ships 60.2 percent natural ores.

Source: Stanford Research Institute Report to the Paulucci Foundation and Annual Reports of Armco and Republic.

Reserve Mining pays the highest royalty, about $1.00 per ton of pellets to the Mesabi Trust, and $0.15 to $0.20 to the owners of the mine property, for a total of about $1.20/ton. The royalty paid by Erie or the smaller mines is about $0.45/ton of pellets.

Reserve and other captive mining companies save on shipping costs to their points of delivery when they ship via captive companies or by long-term contracts with public companies. The average savings is believed to be $0.20/ton over published shipping costs.

The processing costs per se (i.e. excluding transportation, royalties, administration, and taxes) are generally similar for all the companies. No estimates of tailings disposal costs for Erie Mining are available.

## Potential Markets for Taconite

### Domestic

The demand for taconite ore is a derived demand in that mining and beneficiation of ores have been developed in response to the increased utility of this material in the steelmaking process. Thus, the mineral will be mixed and processed at a rate which reflects the market demand for steel, the relative utility of the material in present technology, the cost of the material delivered, and the costs or savings in making hot iron and steel.

Since 1955, the popularity of beneficiated and pelletized ores has grown with the conviction of blast furnace operators that significant economies of operation and investment are available. Presently, pelletized ores are approaching an average iron content of 65 percent, which is a sizable improvement over the 55 percent iron content in natural ores available in 1955.

Continued growth of taconite mining depends in a large part on the future of the steel industry. The correlation between growth in U.S. steel production and growth in the GNP is changing as the ratio of steel consumption to expenditures in several economic sectors continues to change. As the strength-to-weight ratios of non-steel materials continue to improve, and as other materials are substituted for steel in structural, packaging, and other applications, the demand for steel will be proportionately lower. Increasingly, more finished products with high steel content, such as automobiles, will be imported, and some continued growth in imports of raw steel may be expected.

Although predictions of future steel demand and domestic steel production are extremely difficult to make, the median of many projections currently appears to be between 2.5 to 3.0 percent annual growth. Based on the 1964 to 1970 average domestic production of about 132.1 million tons per year, raw steel production could approximate 148.5 to 153 million tons by 1975, and 169 to 177 million tons by 1980. However, wide swings outside this range can be expected. The prospects of economic recession or new growth, alterations in present trade relations, changes in government spending, and changes in world tensions will, in the future, influence domestic steel demand. For these reasons production projections beyond 10 years are extremely speculative.

### Influence of Ore Imports

Individual steel mills make projections based on the development of traditional and new markets. Recently, imports have had a major impact on specialty steelmakers. These industries have lost about 15 percent of their potential market, and this has affected potential earnings, since the markup on specialty steel grades is higher than on other steels. The domestic steelmakers have also experienced spiraling costs and will have to regain their competitive position or lose a greater portion of their domestic markets.

The projection of future domestic ore shipments depends on steel production, the utility of individual ores, delivered costs, the investments of integrated steelmakers, and increasing imports.

Ore imports, which were 31 percent of the total ore shipments in 1970, are expected to remain at 3 percent of the total ore shipped in the United States in the future. As indicated in Table 25, which compares future ore shipments for Minnesota, Canada and the United States as a whole, approximately 37 percent of the total shipments is projected to be from Minnesota.

Table 25

Projections of Taconite Shipment to 1980[1]
Millions of Tons of Ore

| | Minnesota | Domestic Total | Canada | Total Net Imports | Total Shipments to United States |
|---|---|---|---|---|---|
| 1970 | 54.0 | 86 | 27 | 38 | 124 |
| 1975 | 47 to 51 | 85 | 29 | 39 | 124 |
| 1980 | 45 to 54 | 91 | 32 | 40-42 | 133 |

[1] Source: Stanford Research Institute.

### Influence of New Technology

Improved technology and production cost savings appear to be the most flexible cost areas for the future. Labor and equipment costs are expected to continue to rise, and the best opportunities for increases in productivity appear to be through increased use of automation. Current areas of development also include improved material inputs for faster processing, tighter production schedules, and reduced production losses. The greatest technological advance in the near future is expected to be the direct reduction of beneficiated and pre-reduced ores. This process would bypass the blast furnace melting-reducing stage altogether. The greatest potential savings lie in capital cost reduction, production flexibility, and longer term production cost stability. Several large steelmakers, Armco among them, have conducted tests to determine operating parameters.

The desire of integrated mills (those having their own sources of ore) to control and even reduce costs will be the determinant of the Minnesota taconite industry's future. The ore reserves available will have to be cost-competitive with ores available elsewhere. Most large steel companies have several large sources of ore, so that when one source experiences increased costs for whatever reason, they are able to rely on increased shipments from other mines. Taconite processing plants that are approaching 20 years in age are possibly not competitive in terms of steelmaking costs when the tax climate, the cost of continued mining and processing, shipping costs, remaining depreciation, and the quality of the product are taken into consideration.

The Stanford Research Institute examined the competitive position of the Minnesota taconite industry for the Paulucci Foundation in 1971 and concluded that Minnesota will continue to supply the Great Lakes Region in the near future. Canadian ores originating in Quebec are closely competitive, however, and have a lower silica content. Work is currently underway in Minnesota to improve the taconite pellet quality by reducing silica content and increasing the iron content. This could reduce iron and steel production costs while maintaining the Minnesota ore's competitive position.

## Regional Economic Effects

The mining and pelletizing operations of Reserve Mining Company are a major factor in the economy of the State of Minnesota. The following discussion highlights the economic impact of employment and taxes attributed directly to Reserve Mining as well as the impact of the related industries and services dependent on Reserve Mining.

The economic effects directly related to the taconite and natural ore industries were analyzed in a report "The Economic Importance to Minnesota of its Iron Ore Industry" by Professor Eugene P. Pfleider, Gerard Kulbieda, and Alan King, of the University of Minnesota. The study was sponsored by the Minnesota Iron Range Resources and Rehabilitation Commission and the Upper Great Lakes Regional Commission. The data presented in the Pfleider report were a major source for the ROY F. WESTON estimates of the regional economic impact of Reserve Mining.

Employment in the mining industry in Minnesota in 1969-70 was approximately 13,100, of which the taconite segment accounted for 9,600, or 73 percent. On the basis of the estimated average wage of $10,000 per year, total annual mining wages were approximately $130,000,000. Industries related to mining, such as railroads, power, dock loading, and various supply and service industries (personal, financial, and governmental), were estimated in the Pfleider report to account for an additional 12,500 jobs with an annual payroll of approximately $125,000,000. Thus, total employment in mining and related industries and services is estimated to be 25,600, and total wages $255,000,000 per year. If each job is assumed to support an average of four people, the total number of people dependent on Minnesota's mining industry is 102,400 (the Pfleider report estimated 107,000). Reserve Mining employs some 3,000 people and has a payroll of approximately $27,000,000. Related industries and supply and service establishments are estimated to employ 2,700 people and generate an annual payroll of $27,000,000.

The Minnesota Taconite (tax) Amendment passed in 1964 was instrumental in encouraging further expansion of all taconite processors. It guaranteed that the tax on taconite, in lieu of the ad valorem tax on natural ore passed in 1941, would not be changed for a period of 25 years. Other current taxes include an occupation tax in lieu of the state corporate tax on iron mining companies, a royalty tax to be paid by the mining company on royalty payments to land owners, and excise taxes were applicable.

State and local taxes are another measure of the economic influence of the mining industry; in 1969 these taxes, as indicated in the Pfleider Report, amounted to $32,724,000. Related industries and service industries are estimated to contribute $15.2 million dollars. The gross earnings tax on companies and railroads was estimated to be $3.9 million, and income tax on Royalty income was $2.2 million dollars. The total revenue to the state of Minnesota is thus approximately $54 million dollars. Of this total, Reserve Mining pays approximately 3.2 million dollars, and the taxes paid by related and service industries and employees are estimated to be 3.6 million dollars. The royalty tax paid by the fee owner (the owner of the mine property) is about $0.8 million. The total taxes paid by Reserve and related industries and services is thus approximately $7.6 million per year, or 14 percent of the total state and local tax revenues from mining and related sources. The division of these benefits between local and state governments is covered in the Pflieder report.

## Financial Review

The Minnesota Pollution Control Agency in a discovery proceeding, retained Dr. Glenn Berryman, Professor and Chairman of the Accounting Department at the University of Minnesota, to review the economic and financial aspects of Reserve Mining's operation at Silver Bay. Dr. Berryman's investigations included a review of Reserve's financial reports for 1967 through 1969, the company's operating costs, statements of shipments to Armco and Republic Steel, Federal Income Tax liability, and other financial data pertinent to his investigation. Dr. Berryman was able to determine the effect on profitability of the addition of pollution control facilities and to make a limited analysis of net outlay by Reserve if the Company were to close down. From his evaluation, Dr. Berryman testified at the 1969-70 Lake Superior Enforcement Conference that the Company would continue as an economically viable unit, if Reserve Mining's Proposal No. 2 (the disposal of all tailings near the Babbitt Mine as developed by Trygve Hoff and Associates) were implemented.

The return on investment at Reserve for the period of 1967 through 1969 is shown in Table 26. The supporting data useful in this type of an evaluation are shown in Table 27.

The effect on Reserve's earnings of the installation of pollution control facilities was examined by Dr. Berryman. In his calculation he assumed that Reserve's Proposal No. 2, "Disposal of Tailings Near Taconite Mine" prepared by Trygve Hoff and Associates with a capital cost of $74,132,000 was implemented. The annual cost with this alternative was estimated at $12,490,000. The calculations to determine the resulting adjusted 1969 book profit of $0.79 per ton of pellets shipped are shown in Table 28. The supporting calculations for Federal Income tax are also shown in Table 28.

A similar examination was made by ROY F. WESTON following the approach used by Dr. Berryman, to determine the adjusted book profit for 1969 using the cost estimates for the most expensive and least expensive alternatives developed by ROY F. WESTON. The most expensive alternative, (Alternative No. 1, "Coarse and Fine Tailings are Dewatered, Combined and Transported to Lower Lax Lake Area for Disposal") was estimated to have a capital cost of $74,931,000, with an annual cost of $14,346,000. An adjusted book profit of $0.66 per ton of pellets shipped was calculated, with the computations shown in Table 29. The supporting tax calculations are also shown in Table 29.

The least expensive alternative (Alternative No. 4) developed by ROY F. WESTON, "Fine Tailings Pumped to Lower Lax Lake Area, Coarse Tailings Pushed from Delta", was estimated to have a capital cost of $48,102,000, with an annual cost of $10,301,000. Table 30 shows the calculations for the adjusted 1969 book profit of $0.95 per ton of pellets shipped. The supporting calculations on income tax are also shown in Table 30.

Table 26

Return on Investment, Reserve Mining, 1967-1969

| | 1967 | 1968 | 1969 | Total | 1967-1969 Average |
|---|---|---|---|---|---|
| Taconite Shipped - Tons | 9,443,151 | 9,516,840 | 10,649,188 | 29,609,179 | 9,870,000 |
| Gross Income From Iron Ore F.O.B. Silver Bay | $123,096,000 | $123,680,000 | $138,715,000 | $385,491,000 | $128,497,000 |
| Cost of Ore Delivered to Participants Prior to Federal Income Tax | 102,818,000 | 102,869,000 | 114,048,000 | 319,735,000 | 106,578,000 |
| Book Profit | $ 20,278,000 | $ 20,811,000 | $ 24,667,000 | $ 65,756,000 | $ 21,919,000 |
| Federal Income Tax | 5,560,000 | 6,267,000 | 7,191,000 | 19,018,000 | 6,339,000 |
| Book Profit After Tax | $ 14,718,000 | $ 14,544,000 | $ 17,476,000 | $ 46,738,000 | $ 15,580,000 |
| Profit per Ton | $1.56 | $1.53 | $1.64 | $1.58 | $1.58 |
| Investment as of December 31st | $351,072,000 | $353,070,000 | $355,853,000 | $1,059,995,000 | $353,332,000 |
| Percent Return on original investment and capital improvements | 4.19 | 4.12 | 4.91 | 4.42 | 4.4 |

Source: Dr. Glenn Berryman

## Table 27

## Audited Tax and Cost Summaries

### FEDERAL INCOME TAX

| | 1967 | 1968 | 1969 |
|---|---|---|---|
| Gross Revenue | $123,096,000 | $123,680,000 | $138,715,000 |
| Deductions, including depletion allowance | 110,570,000 | 111,424,000 | 124,690,000 |
| Taxable Income | $ 12,526,000 | $ 12,256,000 | $ 14,025,000 |
| Federal Income Tax | $ 5,560,000 | $ 6,267,000 | $ 7,191,000 |

### TOTAL COSTS

| | 1967 | 1968 | 1969 |
|---|---|---|---|
| Labor, Materials, Supplies, and Miscellaneous | $ 79,666,000 | $ 80,433,000 | $ 93,451,000 |
| Provision for Depreciation, Depletion, and Amortization of Leaseholds | 15,162,000 | 14,811,000 | 13,263,000 |
| Loss (Gain) on Disposal of Property | (7,000) | (11,000) | (54,000) |
| Interest Income (Gain) | (568,000) | (563,000) | (495,000) |
| Other Costs | 8,565,000 | 8,199,000 | 7,883,000 |
| TOTAL COSTS | $102,818,000 | $102,869,000 | $114,048,000 |

Note: "Deductions, including depletion allowance" and "TOTAL COST" were obtained by different auditing procedures.

Source: Dr. Glenn Berryman

## Table 28

## Adjusted Book Profit and Federal Income Tax

Assuming
Capital Cost $74,132,000[1]
Annual Pollution Abatement Cost $12,490,000[1]

### BOOK PROFIT

| | | |
|---|---|---|
| 1969 Book Profit | | $ 24,667,000 |
| Annual Pollution Abatement Costs | | |
| Direct Operating | $ 6,210,000 | |
| Depreciation (20 years) | 2,972,000 | |
| Interest | 3,308,000 | |
| Total Annual Abatement Costs | | 12,490,000 |
| Sub-Total | | $ 12,177,000 |
| Assumed Federal Income Tax (1971 Rates) | | 3,729,000 |
| Adjusted Book Profit After Taxes | | $ 8,448,000 |
| Adjusted Book Profit per Ton of Pellets Shipped (1969 Production Level) | | $0.79 |

### FEDERAL INCOME TAX AT 1971 RATES

| | | |
|---|---|---|
| Total Deductions -- 1969, including Percent Depletion[2] | | $124,690,000 |
| Less Percent Depletion included in Deductions | | 13,976,000 |
| Sub-Total | | $110,714,000 |
| Plus Adjusted Depletion | | |
| Net Income from Property[2] | $27,952,000 | |
| Cost of Pollution Control | 12,490,000 | |
| Adjusted Net Income | $15,462,000 | |
| Income Limit on Depletion (50%) | 7,731,000 | 7,731,000 |
| Total Deductions, including Adjusted Depletion | | $118,445,000 |
| Cost of Pollution Control | | 12,490,000 |
| Sub-Total | | $130,935,000 |
| Gross Income | | $138,715,000 |
| Adjusted Deductions | | 130,935,000 |
| Taxable Income | | $ 7,780,000 |
| Federal Income Tax (48 percent, less $5,500) | | $ 3,729,000 |

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[1] From Proposal No. 2 by Trygve Hoff & Associates, "Disposal of Tailings near Taconite Mine". Capital Cost does not include land, financing costs, interest prior to completion of facilities, production costs, operating supplies, and maintenance parts.

[2] From Reserve Mining's Tax Schedule.

Source: Dr. Glenn Berryman

## Table 29

## Adjusted Book Profit and Federal Income Tax

Assuming
Capital Cost $74,931,000[1]
Annual Pollution Abatement Cost $14,346,000[1]

### BOOK PROFIT

| | | |
|---|---|---|
| 1969 Book Profit | | $ 24,667,000 |
| Annual Pollution Abatement Costs | | |
| Direct Operating | $ 7,229,000 | |
| Depreciation (20 years) | 3,746,000 | |
| Interest | 3,371,000 | |
| Total Annual Abatement Costs | | 14,346,000 |
| Sub-Total | | $ 10,321,000 |
| Assumed Federal Income Tax (1971 Rates) | | 3,285,000 |
| Adjusted Book Profit After Taxes | | $ 7,036,000 |
| Adjusted Book Profit per Ton of Pellets Shipped (1969 Production Level) | | $0.66 |

### FEDERAL INCOME TAX AT 1971 RATES

| | | |
|---|---|---|
| Total Deductions – 1969, including Percent Depletion[2] | | $124,690,000 |
| Less Percent Depletion included in Deductions | | 13,976,000 |
| Sub-Total | | $110,714,000 |
| Plus Adjusted Depletion | | |
| Net Income from Property[2] | $27,952,000 | |
| Cost of Pollution Control | 14,346,000 | |
| Adjusted Net Income | $13,606,000 | |
| Income Limit on Depletion (50%) | 6,803,000 | 6,803,000 |
| Total Deductions, including Adjusted Depletion | | $117,517,000 |
| Cost of Pollution Control | | 14,346,000 |
| Sub-Total | | $131,863,000 |
| Gross Income | | $138,715,000 |
| Adjusted Deductions | | 131,863,000 |
| Taxable Income | | $ 6,852,000 |
| Federal Income Tax (48 percent, less $5,500) | | $ 3,285,000 |

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[1] From Alternative No. 1 by ROY F. WESTON, "Coarse and Fine Tailings are Dewatered, Combined, and Transferred to Lower Lax Lake Area for Disposal". Capital cost does not include land, financing costs, interest prior to completion of facilities, production costs, operating supplies, and maintenance parts.

[2] From Reserve Mining's Tax Schedule.

## Table 30

## Adjusted Book Profit and Federal Income Tax

Assuming
Capital Cost $48,102,000[1]
Annual Pollution Abatement Cost $10,301,000[1]

### BOOK PROFIT

| | | |
|---|---|---|
| 1969 Book Profit | | $ 24,667,000 |
| Annual Pollution Abatement Costs | | |
| Direct Operating | $ 5,731,000 | |
| Depreciation (20 years) | 2,405,000 | |
| Interest | 2,165,000 | |
| Total Annual Abatement Costs | | 10,301,000 |
| Sub-Total | | $ 14,366,000 |
| Assumed Federal Income Tax (1971 Rates) | | 4,255,000 |
| Adjusted Book Profit After Taxes | | $ 10,111,000 |
| Adjusted Book Profit per Ton of Pellets Shipped (1969 Production Level) | | $0.95 |

### FEDERAL INCOME TAX AT 1971 RATES

| | | |
|---|---|---|
| Total Deductions – 1969, including Percent Depletion[2] | | $124,690,000 |
| Less Percent Depletion included in Deductions | | 13,976,000 |
| Sub-Total | | $110,714,000 |
| Plus Adjusted Depletion | | |
| Net Income from Property[2] | $27,952,000 | |
| Cost of Pollution Control | 10,301,000 | |
| Adjusted Net Income | $17,651,000 | |
| Income Limit on Depletion (50%) | 8,825,000 | 8,825,000 |
| Total Deductions, including Adjusted Depletion | | $119,539,000 |
| Cost of Pollution Control | | 10,301,000 |
| Sub-Total | | $129,840,000 |
| Gross Income | | $138,715,000 |
| Adjusted Deductions | | 129,840,000 |
| Taxable Income | | $ 8,875,000 |
| Federal Income Tax (48 percent, less $5,500) | | $ 4,255,000 |

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[1] From Alternative No. 4 by ROY F. WESTON, "Fine Tailings Pumped to Lax Lake Area, Coarse Tailings Pushed from Delta". Capital Cost does not include land, financing costs, interest prior to completion of facilities, production costs, operating supplies, and maintenance parts.

[2] From Reserve Mining's Tax Schedule.

A summary of comparitive earnings for Reserve in 1969 without pollution abatement and under the assumed condition of pollution abatement with the three different alternatives shown in Table 31.

The return on net funds provided by the parent companies, based on the three possible abatement alternatives above, is compared to 1969 rate of return and to the 1967-1969 average rate of return in Table 32. Dr. Berryman's analysis indicated that the average return on net funds (annual funds less amounts included in investments and current assets) for 1967, 1968 and 1969 without pollution abatement facilities was 49.2 percent while the rate of return on net funds in 1969 with no abatement costs was 70.0 percent. With the annual abatement costs included in the calculation, this rate of return would be reduced to between 28.1 and 40.6 percent, depending on the pollution alternative used.

The return on total assets (depreciated investment not including costs of improvement and maintenance which are assumed to be operating costs) is compared for the three alternative abatement schemes in Table 33. This calculation is known as the "accountant's rate of return" and is not to be construed as return on original investment. This rate of return on total assests for 1969 without pollution abatement was 7.3 percent: with pollution abatement this rate of return would be reduced to 3.0, 2.5, or 4.0 percent, depending on the abatement alternative selected.

## Effect of Closing Down the Silver Bay Plant

Since the start of operations at Silver Bay in 1956, Reserve Mining has been able to use once-through process water and discharge the taconite tailings, without treatment, to Lake Superior. This should have provided Reserve Mining with a competitive advantage over the other taconite companies, which have had to bear the financial burden of water treatment (for reuse) and pollution abatment costs. The impending requirement for pollution abatement facilities at Silver Bay brings new factors into the picture, including possible closing of the Silver Bay plant. The increased cost of operation with pollution abatement facilities would be reflected in lower earnings and a lower rate of return on investment by both parent companies. It is difficult to predict what effects these impending increased costs will have on management's decision regarding continued operation of Reserve Mining.

The decision, whether to incur these pollution abatement costs and continue to operate, or to phase out operations and close down the plant, is influenced by the following factors:

1. The availability of other sources of ore to fill the potential iron deficiency if Reserve is closed must be a prime consideration. Reserve Mining currently provides 60 percent of Armco's ferrous input and 45 to 50 percent of Republic's assuming that no ore is sold. To replace this source would require additional sources and possibly new expense. However, no reliable information about the relative advantage or the availability of new large ore sources is available, and no firm comparisons can be made without detailed study and disclosure by the parent companies. If the existing plant can be operated for 10 more years with no new major capital outlay, the investment will be approximately 80 percent depreciated and a gradual changeover to new, more efficient production facilities could be made with no further impetus.

2. The projected costs of continued operation at Silver Bay with abatement facilities must be compared to projected production costs at a new plant elsewhere, before

## Table 31

### Comparison of Earnings for Implementation of Various Pollution Abatement Alternatives[1]

| | Book Profit (After Taxes) | Profit per Ton |
|---|---|---|
| No Abatement | $17,476,000 | $1.64 |
| Trygve Hoff Proposal 2<br>- Annual Abatement Cost $12.5 million | $ 8,448,000 | $0.79 |
| ROY F. WESTON Alternative 1<br>- Annual Abatement Cost $14.3 million | $ 7,036,000 | $0.66 |
| ROY F. WESTON Alternative 4<br>- Annual Abatement Cost $10.3 million | $10,111,000 | $0.95 |

[1] Based on 1969 production of 10,650,000 tons.

## Table 32

### Return on Net Funds Provided by Parent Companies with Implementation of Various Pollution Abatement Alternatives[1]

| | Average 1967-69 | 1969 | for Annual Pollution Abatement Costs of | | |
|---|---|---|---|---|---|
| | | | $12.5 million | $14.3 million | $10.3 million |
| Funds provided by Parent Companies | $56,056,000 | $56,056,000 | $56,056,000 | $56,056,000 | $56,056,000 |
| Net Funds | 31,642,000 | 24,946,000 | 24,946,000 | 24,946,000 | 24,946,000 |
| Book Profit After Taxes | $15,580,000 | $17,476,000 | $ 8,448,000 | $ 7,036,000 | $10,111,000 |
| Rate of Return on Net Funds provided by Parent Companies | 49.2% | 70.0% | 33.9% | 28.1% | 40.6% |

[1] Based on 1969 operating conditions.

## Table 33

### Projected Return on Total Assets Excluding Amounts Due from Participants with Implementation of Various Pollution Abatement Alternatives

| | 1969 | for Annual Abatement Costs of | | |
|---|---|---|---|---|
| | | $12.5 million | $14.3 million | $10.3 million |
| Total Assets from 1969 (From Financial Statements) | $238,096,000 | | | |
| Less amounts due from parent companies at end of year | 31,112,000 | | | |
| Current Assets | $206,984,000 | $206,984,000 | $206,984,000 | $206,984,000 |
| Capital Cost of Abatement Plan | | 74,132,000 | 74,931,000 | 48,102,000 |
| Total Assets (Adjusted) | | $281,716,000 | $282,515,000 | $255,686,000 |
| 1969 Book Profit After Tax | 17,500,000 | 8,448,000 | 7,036,000 | 10,111,000 |
| Rate of Return on Total Assets (Adjusted) | 7.35% | 2.99% | 2.49% | 3.97% |

a decision to closedown operations can be made. The abatement facilities could shorten the economic life of the Reserve plant unless other efficiencies can be implemented to compensate for this unproductive capital investment.

3. The demand for large increases in ore supply would be a prime consideration in changeover. Such large increases could encourage early change to more efficient relocated facilities.

4. The pace of technical advancement in the industry is also important, inasmuch as it could reduce production costs at a new plant sufficiently so that the practical life of the existing works would be shortened through obsolescense. The current opinion of mining consultants is that a reduction in the silica content of taconite pellets will be the next breakthrough. A one percent increase in iron content of the pellets would provide approximately $2,500,000 additional revenue per year at Reserve Mining.

5. If sizable pollution abatement expenses are incurred and the plant does become obsolete before the projected end of its economic life, the company's earnings will be reduced and its industry position will be adversely affected. The risk involved in relocation must be studied, along with other changing operational parameters, which are of a proprietary nature and generally not disclosed.

The cost involved obviously will be a major factor in management's decision to close down or to continue operation. The cost of closing down, as determined by Dr. Berryman and including the balances due on bonds and notes and estimates of salvage value, pensions, severance pay, and miscellaneous closing costs, is presented in Table 34. From these calculations, it appears that it would cost Reserve Mining between 74 and 75 million dollars to close down.

## Table 34

## Estimated Net Loss from Closing Down of Facilities

| | | |
|---|---|---|
| Balance due on First Mortgage Bonds as of December 31, 1971 | | $135,511,000 |
| Principal Outstanding on Promissory Notes[1], less a Tax Benefit | | 1,021,000 |
| Tax Benefits arising from uncollectability of First Mortgage Notes Receivable | | (4,611,000) |
| Tax Benefits arising from abandonment of property, plant, and equipment | | (49,800,000) |
| Sub-Total | | $ 82,121,000 |
| Miscellaneous Closing Costs | | |
| Pension | $5,700,000 | |
| Severance pay for 90 percent of work force | 1,000,000 | |
| Relocation payments for 10 percent of work force | 120,000 | |
| Miscellaneous costs | 500,000 | 7,320,000 |
| Sub-Total | | $ 89,441,000 |
| Less Salvageable Equipment and Scrap, at 7 percent of current value of assets | | 15,000,000 |
| Net Loss from Closing Down of Facilities | | $ 74,441,000 |

[1] 5-1/2 percent Promissory Notes of Silver Bay Housing Corporation, guaranteed by the participants in Reserve Mining Company.

Source: Dr. Glenn Berryman

## Summary Discussion

To facilitate comparison, pertinent facts relative to five selected water pollution control alternatives are tabulated in Table 35. Inclusion of these alternatives in this table is not to be construed as an assumption that they are the only feasible alternatives. In addition, the table includes pertinent data relative to existing tailings disposal practice.

The statistical information is self-explanatory. The information relative to "Technical Feasibility" and "Compliance with Regulatory Requirements" requires explanation.

The Technical Feasibility of the Trygve Hoff Proposal No. 2 has been indicated as questionable because the system, as reported, has no blowdown. It is believed that the concentration of dissolved solids in the recycled process water will require blowdown to prevent interference with the beneficiation process. Addition of an adequate blowdown treatment system, at increased construction and operating cost, would overcome the limitation of the proposed system Furthermore, it is believed that the proposed disposal of mine tailings into an active mine would cause undue interference with the mining operation; a different disposal location would be required to overcome this limitation.

Technical Feasibility is questioned relative to the Reserve Mining Modified Plan (Proposal No. 20) because of the complexity of the submerged discharge system The need for extending the pipeline system due to solids accumulation could present serious operational problems. This alternative does not comply with the technical requirements of WPC 15, according to the June 3, 1971 "Report for Informal Hearing on Alleged Violations of Lake Superior Water Quality Standards by Reserve Mining Company, Silver Bay, Minnesota". Likewise, the existing practice for tailings disposal does not comply with WPC 15.

ROY F. WESTON Alternative No. 4 has been given a "Qualified No" under "Compliance with Regulatory Requirements". The "No" is qualified because the alternative calls for water's edge disposal of washed and dewatered coarse tailings. Although it is believed that the actual and/or potential environmental impact will be imperceptible, water's edge disposal may be considered to be in technical violation of regulatory requirements. The development of adequate markets for tailings could eliminate the need for water's edge disposal.

Table 35

Comparison of Tailings Disposal Alternatives

| Evaluation Item | Present Practice | Reserve Mining Modified Plan Proposal No. 20 | Trygve Hoff Proposal No. 2 | ROY F. WESTON Alternative No. 1 | ROY F. WESTON Alternative No. 4 | Plant Shutdown |
|---|---|---|---|---|---|---|
| Capital Cost of Pollution Control Facilities | None | $14,000,000 | $74,132,000 | $74,931,000 | $48,102,000 | None |
| Annual Cost of Pollution Control | Nominal | >$2,400,000 | $12,490,000 | $14,346,000 | $10,301,000 | None |
| Adjusted Book Profit After Taxes[1] | $17,476,000 | <$16,116,000 | $8,448,000 | $7,036,000 | $10,111,000 | None |
| Loss in Book Profit due to Implementation of Pollution Control | None | >$1,360,000 | $9,028,000 | $10,440,000 | $7,365,000 | $17,476,000[2] |
| Rate of Return on Total Assets[1] | 7.35% | <7.30% | 2.99% | 2.49% | 3.97% | None |
| Rate of Return on Net Funds Provided by Parent Companies[1] | 70.0% | <64.6% | 33.9% | 28.1% | 40.6% | None |
| Water Discharge to Lake | 412,000 gpm | 300,000 gpm[3] | None | 25,000 gpm | 25,000 gpm | None |
| Suspended Solids Discharged to Lake | 60,000 LTPD | 60,000 LTPD | None | <2.5 LTPD | 30,900 LTPD[4] | None |
| Reduction of Suspended Solids Discharge to Lake by Pollution Control | None | None | 100% | 99.9% | 48.5% | 100% |
| Reduction of Surface Area Discharge to Lake by Pollution Control | None | None | 100% | 99.8% | 97.7% | 100% |
| Technical Feasibility | N.A. | Questionable | Questionable | Yes | Yes | N.A. |
| Compliance with Regulatory Requirements | No | No | Yes | Yes | Qualified No | Yes |

[1] Based on 1969 earnings.
[2] Plus cost of closing down the plant, which would be >$74,000,000.
[3] Estimated.
[4] Assumes utilization of coarse tailings for dam construction, but no utilization for other purposes.

N.A. – Not Applicable
gpm – gallons/minute
LTPD – long tons/day

# APPENDIX A

# EVALUATION OF TACONITE AS AGGREGATE - TEKOLOGY CORPORATION

T-A MATERIALS, INC.
BERGEN AND EDSALL BOULEVARDS • PALISADES PARK, NEW JERSEY 07650

July 16, 1971

Mr. M. Fiore
Roy F. Weston
Lewis Lane
West Chester
Pennsylvania 19380

Subject: Taconite Tailings

Dear Mike:

Confirming our telephone conversation today we have produced three sample bricks from the taconite you submitted. Our tests show the following:

| Code No. | Compressive Strength P.S.I. | Absorption % - 24 hrs. |
|---|---|---|
| 1138-A | 6,250 | 6.68 |
| 1138-B | 7,250 | 6.90 |
| 1139 | 5,500 | 7.76 |

One sample of each brick with the code number shown above is being sent to you today by parcel post marked to your attention. Please note that we have added no coloring but Dr. Blengsli, our Research Director, tells me that these bricks can be easily colored with iron oxide pigments.

It would appear that we can successfully make good bricks and blocks from taconite and as I suggested, I think the next step is probably for you and your associates to visit with us here in Palisades Park.

I am sending you with this letter an invoice for the $150 test charge that you agreed to pay under your W.O. 300-20 dated June 23, 1971.

Sincerely,

TEKOLOGY CORPORATION
(formerly T-A Materials)

Jim Ryan

President

James R. Ryan
-sw-

CC: Mr. R. Weston
Mr. M. Woldman

TELEPHONE: 201-944-2[illegible] TWX 201-947-0825 CABLE: "TEKNOLOG"

T-A MATERIALS, INC.
BERGEN AND EDSALL BOULEVARDS • PALISADES PARK, NEW JERSEY 07650

July 23, 1971

Mr. Michael L. Woldman
Roy F. Weston, Inc.
Lewis Lane
West Chester, Pennsylvania 19380

Dear Mike:

Subject: Taconite--Tek Process

Attached is a copy of Dr. Blengsli's memo of July 22 to me, which, I believe, is self-explanatory and gives you the information you requested.

It did not appear to us that for the purposes of your report you absolutely required a cost quotation at this time on what Dr. Blengsli is recommending. What we suggest you do is to write your report, and if you, the mining company, or the Government want a firm quotation, we would then promptly work up the details. At this time, without knowing exactly what would be required of us, it simply is not even possible to give an order of magnitude.

If you have any additional questions, please call Dr. Blengsli or myself.

Sincerely yours,

TEKOLOGY CORPORATION
(formerly T-A Materials, Inc.)

James R. Ryan
President

James R. Ryan
-lf-
Attachment

cc: Mr. Michael E. Fiore

TELEPHONE: 201-944-2221 TWX 201-947-0825 CABLE: "TEKNOLOG"

TEKOLOGY CORPORATION

## INTEROFFICE MEMORANDUM

To: Mr. J. R. Ryan

Date: July 22, 1971

Report from the Research Laboratories

Re: Taconite evaluation as aggregate

A sample of Taconite was submitted by Roy F. Weston, Inc., Lewis Lane, West Chester, Pennsylvania, for evaluation as a possible raw material for the Tek Process brick production. The Taconite sample, as received, had the physical appearance of being suitable as an aggregate for the Tek Process, except for its size grading, which was generally too coarse for immediate use.

After proper size adjustment, initial experiments with the material indicated that, indeed, the Taconite can serve as a raw material for the Tek Process, and it is earnestly recommended that further work be done to substantiate these initial observations and findings.

One brick of each of three different experiments were submitted to Roy F. Weston, Inc., and had the following properties:

| Code No. | Compressive Strength P.s.i. | Water Absorption % |
|---|---|---|
| 1138-A | 6,250 | 6.68 |
| 1138-B | 7,250 | 6.90 |
| 1139 | 5,500 | 7.76 |

These are extraordinarily high values for compressive strength and low values for water absorption. The minimum requirements in corresponding values for the highest grade clay brick are 3,000 p.s.i. and 8.2 % absorption, and for concrete bricks, 3,500 p.s.i. and 8.2 % absorption.

The above tabulated values for the Taconite bricks, obtained at a cement use level of 10%, indicate that the cement use level can be substantially reduced. The use level of our chemicals applied in conjunction with cement will probably not be reduced. However, since the cost of chemicals is relatively minor, compared to the cost of cement, emphasis should be placed on the possibility that for bricks or blocks of back-up or internal use, the cement use level might very well be reduced to 5%, and even possibly 4%; for face bricks the cement use level may very well come down to 6%.

To illustrate the effect of cement use level on the ex-factory cost of standard bricks, an excerpt from our general bulletin on Tekbrik cost vs. cost of aggregate for various use levels of cement follows:

> In the following table is summarized typical production costs for U.S.A. standard Tekbriks (size 7-5/8 x 3-5/8 x 2-1/3 inches) in $ per 1000 units vs. cement content vs. cost per ton of aggregates (lime rock or similar):

| Cement Content: | A - 10% | | | B - 6% | | C - 4% | |
|---|---|---|---|---|---|---|---|
| Cost of aggregate, $ per ton; | 2.50 | 2.0 | 1.0 | 2.0 | 1.0 | 2.0 | 1.0 |
| Cost of raw materials, | 10.00 | 9.10 | 7.14 | 7.45 | 5.35 | 6.62 | 4.45 |
| Operating Expenses, | 10.75 | 10.75 | 10.75 | 10.75 | 10.75 | 10.75 | 10.75 |
| Cost of Product, | 20.75 | 19.85 | 17.89 | 18.20 | 16.10 | 17.37 | 15.20 |

If pigmentation is required - for face brick only - add $2.00 per 1000 units.

Although our initial experience with the Taconite have been extraordinarily favorable, or perhaps, rather, due to the extraordinary results obtained, it would seem imperative that a further laboratory project be initiated to prove beyond question that the Taconite may be basic to a substantial industrial development.

It is suggested that further work on this raw material be conducted in two distinct phases: First, a laboratory study of pertinent process factors, followed by laboratory production of adequate products for quality tests; Second, a pilot plant study of operational factors if deemed necessary.

The first phase, the laboratory operation, may require from 2 to 6 months, depending on urgency and intensity of the operation. This is a phase which Tekology Corporation would have pre-eminent background and equipment to perform.

Since Tekology has a pilot plant ready for problems and projects of this type, the pilot plant phase might be performed in the course of a few days, depending on the extent of experimental products required. It may be well to state that the pilot plant is capable of operating at a rate of 5000 bricks per day, and that a block pilot plant is available at an associate organization.

HLB:lf

H. L. Blengsli

# APPENDIX B

## TAILINGS UTILIZATION IN THE CONSTRUCTION OF A RECREATIONAL SKIING AREA

The utilization of tailings in the construction of a ski area, or augmenting the slope of an existing hill to enhance its potential as a ski slope is examined in this section. Such constructed or improved slopes would hopefully draw visitors from Mineapolis-St. Paul, Duluth, and high-density areas in Wisconsin.

The area north of Silver Bay in the vicinity of Bear and Bean Lakes has ridges and contours of 200 feet vertical difference in elevation that could be improved readily. If dry tailings or a slurry could be conveyed to these areas (2 or 3 miles), several ski runs of 1/2 mile or longer and with vertical drops of 200 to 400 feet could be constructed at a future date.

### Analysis of Recreational Skiing Needs for Duluth and Vicinity

The skiing season on the northern shore of Lake Superior generally extends from Thanksgiving to the end of March, with peak activity from mid-December to mid-March. Snow conditions are favorable and temperature is only occasionally too low for extensive activity. (This cold snap lasts approximately 2 weeks in January and February.) Average snowfall is approximately 60 inches, and average temperatures are 20°F in December, 6°F in January, 8°F in February, 15°F in March.

The State of Minnesota currently has between 40 and 50 ski areas. The 1968 Minnesota Outdoor Recreation plan lists 39 areas (Table B-1), of which six are in St. Louis, Lake, and Cook Counties on the north shore of Lake Superior. One of the more popular places, a weekend resort, is 100 miles northeast of Duluth at Lutsen. A new resort would, thus, have to compete with these areas and actually offer some improvement over existing elevations, quality of ski runs, and associated facilities.

The major ski areas and the ones enjoying the greater popularity are those located in the vicinity of St. Paul-Minneapolis. The areas are generally small in size, intensively used, augmented with snowmaking equipment, and well maintained. Of all the Great Lakes states, Minnesota has had the greatest growth in vertical transport (feet/hr.) or skier lift capacity, but this appears to be tapering off since 1968. Skier visits increased appreciably until 1966, but have fallen off since then due to the slower rate of area growth. Table B-2 gives estimates of skier visits in the Great Lakes region, based on eligible population and income per household.

#### Skier Profile

The Great Lakes Region skier skis only half as many days as the western skier and one third as many as the eastern skier. Since more than 80 percent of ski trips are single-day trips with an average travel distance of 68 miles one way or weekend trips averaging 237 miles, the opportunities for large and profitable ski development are limited. While the close proximity of a ski areas to a place of residence was the single most important factor for single-day trips, physical qualities of the slopes were of paramount importance to the weekend or vacation ski enthusiast. The day skier is concerned more with the physical qualities of the slope, while the weekend or vacation skier concerns himself with the area's reputation among skiers. Table B-3 summarizes the various motives affecting ski area selection both by the single-day and the weekend or vacation skier.

## Development Potential

In describing the potential market for ski development in the Northeast Recreation Region 3 of the State of Minnesota, one must consider the proximity of the ski area to the day skier and proximity of the better-known and more fashionable ski resorts to the weekend and vacation skier. As was indicated previously, most of the skiers in the Great Lakes Region are day skiers.

The ski area under consideration is located approximately 200 miles north of the Twin Cities and approximately 500 miles north of Chicago. Considering the abundance of ski areas (approximately 20) in the Metropolitan Twin Cities Area, it is highly unlikely that the Duluth or other northern areas will serve this skier group.

In contrast to the day skier, the weekend or vacation skier will prefer to ski in places of greater reputation and prestige, such as the western states. Increased airline mobility and various discount tours make the Rocky Mountain area more attractive to this group of skiers. Therefore, potential return on investment is currently uncertain and difficult to project. A recent study, "Skiing in the Great Lake States", views the investment possibility as generally poor based primarily on past performance, uneven use of facilities (i.e. over or under capacity), high competition from the major U.S. and European ski resorts for the youth market, and the industry's natural dependency on favorable weather conditions.

Projections for the 1975-76 for the Great Lakes Region, as prepared in the "Skiing in the Great Lakes Study", estimates the development of 212 ski areas with approximately 4,300 skiers visiting each site.

The cost of establishing a resort after a hill is constructed from discarded tailings is estimated to be approximately $1.2 to $2.5 million dollars. The lower figure includes one chair lift (and its required machinery) and two smaller lifts. Since the area would be one that is continually expanding as tailings are generated, it would be expected that a major investment of 1.2 million dollars would not be made until after approximately 10 years of tailings deposition. If skiing remains popular, the region prospers and the population grows, the attractiveness of continued development as a winter resort should be restudied. It does not appear at this time that a ski resort in the Silver Bay area would draw heavily from population centers in Wisconsin and Illinois, because there are several good ski areas with comparable vertical drops between Chicago and Diluth.

An investment of 1.2 to 2.5 million dollars in the vicinity of Silver Bay would thus be a large risk, and the additional cost of tailings deposition on an existing hill, construction of settling basins at the foot of the slope, and continued maintenance would not be warranted unless there was assurance of a strong market for skiing recreation in the future.

An alternative course of action would be to deposit the tailings in the vicinity of Lax Lake for the time being, and then at a future date, dredge the tailings or transport them to form or augment a hill if the skiing market improves.

## Table B-1

## Minnesota Ski Areas-1968/69 Season

1. Afton Alps
2. Arctic Park
3. Benton Valley
4. Buffalo Valley
5. Buck Hill
6. Buena Vista
7. Cedar Hills
8. Como Park
9. Detroit Mountain
10. Eko Backen
11. French Rapids
12. Frontenac
13. Giant's Ridge
14. Hallaway Hill
15. Hidden Valley
16. Hyland Hills
17. Inver Hills
18. Little Squaw Valley
19. Lookout Mountain
20. Lusten
21. Mont Du Lac
22. Mt. Itasca
23. Mt. Rockwood
24. Old Smokey
25. Pine Bend
26. Powder Ridge
27. Quadna Mountain
28. Ski Devil
29. Ski Gull
30. Ski Haven
31. Ski Tonka
32. Sugar Hills
33. Tartan Park
34. Theodore Wirth
35. Timberlane
36. Val Chatel
37. Val Croix
38. Villa Park
39. Welsh Village

Source: Minnesota Outdoor Recreation Plan - 1968.

NOTE: A significant number of Minnesota skiiers ski at facilities in Wisconsin and Michigan.

## Table B-2

### Estimates of Skier Visits in Great Lakes Region

|  | Projection |  |  | Estimated Study Area |  |  |
|---|---|---|---|---|---|---|
| Season | Estimated Actual Number | A Number | B Number | Population Thousands | Income per Household Dollars | Areas Number |
| 1960-1961 | 669 | 699 | 777 | 30,171 | 6,763 | 112 |
| 1961-1962 | 930 | 960 | 894 | 30,415 | 6,614 | 124 |
| 1962-1963 | 1,241 | 1,220 | 1,168 | 30,751 | 6,883 | 132 |
| 1963-1964 | 1,494 | 1,482 | 1,453 | 31,166 | 7,090 | 142 |
| 1964-1965 | 1,842 | 1,741 | 1,790 | 31,577 | 7,401 | 152 |
| 1965-1966 | 1,866 | 1,998 | 2,109 | 31,944 | 7,789 | 159 |
| 1966-1967 | 2,489 | 2,247 | 2,384 | 32,248 | 8,377 | 148 |
| 1967-1968 | 2,318 | 2,503 | 2,295 | 32,659 | 8,520 | 148 |
| 1975-1976 |  | 4,388 | 4,124 | 34,978 | 10,210 | 212 |

## Table B-3

### Motives for Choosing Ski Areas

| Motive | Single-day Trips | Weekend or Vacation Trips |
|---|---|---|
| Closeness to residence | 72.0 | 78.0 |
| Physical quality of slopes | 61.5 | 43.2 |
| Presence of cable facilities | 39.2 | 30.7 |
| Low price of tow and lift tickets | 30.5 | 29.2 |
| Area's reputation with skiers | 23.8 | 26.1 |
| Expected amount of crowding | 22.1 |  |
| Reputation for after-ski entertainment | 10.5 | 20.8 |
| Other | 10.0 | 15.5 |
| Advertising | 6.4 | 15.4 |
| On-site eating, drinking, and/or lodging facilities | 6.0 | 10.2 |
| Number of other ski areas in vicinity | 4.3 | 7.8 |
| No motive mentioned | 13.6 | 9.0 |
| Total responding | 300.0 | 300.0 |

# APPENDIX C

## OPERATIONS ANALYSIS

Reserve Mining Company C-1

Erie Mining Company C-7

Eveleth Taconite Company C-15

Lind-Greenway Mine C-20

# APPENDIX C

# OPERATIONS ANALYSIS

## Reserve Mining Company

### General

Reserve Mining Company is located at Silver Bay, Minnesota, on the south shore of Lake Superior. The company is jointly owned by Republic Steel Corporation of Cleveland and Armco Steel Corporation of Middleton, Ohio.

Reserve produces merchantable iron ore in the form of pellets from Babbitt taconite, a hard, gray rock in which are imbedded fine particles of magnetite, a black magnetic oxide of iron. The problems of concentrating Reserve's magnetite are somewhat different than those from the Mesabi taconites to the west. The Reserve taconite is somewhat easier to grind and has a higher content of magnetite than most Mesabi taconites. However, it contains more partially-magnetic silicates, together with leaner magnetic middlings, which makes the ore somewhat more difficult to concentrate.

Currently, production from the Babbitt Mine averages about 33 million long tons per year of taconite (containing 23.5 percent of iron), from which 10.8 million long tons per year of concentrated pellets (containing 62.5 percent iron) are produced by the plant at Silver Bay.

Mining is done at Babbitt, Minnesota. After primary and secondary crushing to the size of about 4 inches, the crude taconite is transported on Reserve's 47-mile intra-plant railroad to the processing plant at Silver Bay. Diesel-electric locomotives are used to haul trains averaging 140 cars. Each car has a capacity of 85 long tons and is equipped with a specially designed swivel coupling, which permits dumping without uncoupling the cars from the train. The cars are dumped at Silver Bay in a huge rotary dumper, which turns two cars over at a time.

The processing of taconite at Silver Bay begins when the 4" crude ore is crushed in two stages into pebbles smaller than 3/4" in size. These are then fed into the Concentrating Plant, which consists of twenty-two mill lines (called "Sections"). Each section (with minor exceptions) consists of one Rod Mill, two Cobber Magnetic Separators, two Ball Mills, eight Rougher Magnetic Separators, eight Dorrclones, two Hydroseparators (also called Siphon Sizers), six Finishing Magnetic Separators, six Primary Cyclones, one Regrind Ball Mill, two Secondary Cyclones, two Finishing Hydroseparators, and one Disc Vacuum Filter. Each section is capable of processing 140 to 180 long tons per hour of crude ore, with an average of 168 long tons per hour.

Sections 1 through 12 (original facilities) are located in the West side of the Concentrating Plant, and Sections 101 through 110 (new facilities completed in 1961) are located in the East side of the concentrating plant. Each concentrator section is capable of independent operation except for sharing the plant water supply header. Power distribution, wastewater discharge systems, and other facilities are separate. Equipment arrangement is similar but not the same dimensionally; thus, modifications and additions required would vary in detail between the East and West sections. The original West sections (1 through 12) were updated during the 1965-66 plant expansion program and these processing lines are considered to be basically the same in operation and capacity. The only exception is Section No. 3, where four units of 10'-wide by 3'-diameter Rougher Permanent Magnetic Drums are used instead of the eight units of 4'-wide Inclined-Belt Rougher Magnetic Separators used in each of the other twenty-one sections. Slightly better solids separation is obtained and less water is used at the Rougher Permanent Magnetic Drum portion of Section No. 3; however, the difference in the overall solids balance and water usage among the twenty-two sections is not significant.

Wastewaters containing tailings from the Concentrating Plant are discharged through a series of pipes, troughs, and branch launders to the main East and West Flumes (inside the Concentrating Plant Building) before final discharge to the lake. In addition to water used at various points in the individual sections, water is used at several points along the main East and West Flumes and at the West Launder to help flush the solids and prevent deposits. The East Sections (ten mill lines) of the concentrating Plant were built at an elevation 15 feet higher than the West Section and, therefore, use less flushing water than the original West Sections (twelve mill lines). Approximately two tons of waste material (called "tailings" and ranging in size from 5/8" down to less than 5 microns) are produced for every three tons of crude ore processed. During the 1967-71 period, Reserve discharged an average of 60,000 long tons per day of tailings, almost all of which were generated from the Concentrating Plant.

After the finely-ground, iron-rich concentrate is dewatered at the vacuum filters, it is transferred to the Pelletizer Plant by conveyors. Bentonite clay is then added to the concentrate, and the mixture is formed into 3/8 to 1/2 inch "green" pellets in Balling Drums. These are made hard and porous by baking them at a temperature of 2,400°F in Horizontal Pelletizing Furnaces. Thus, the magnetite is converted into hematite in the final process.

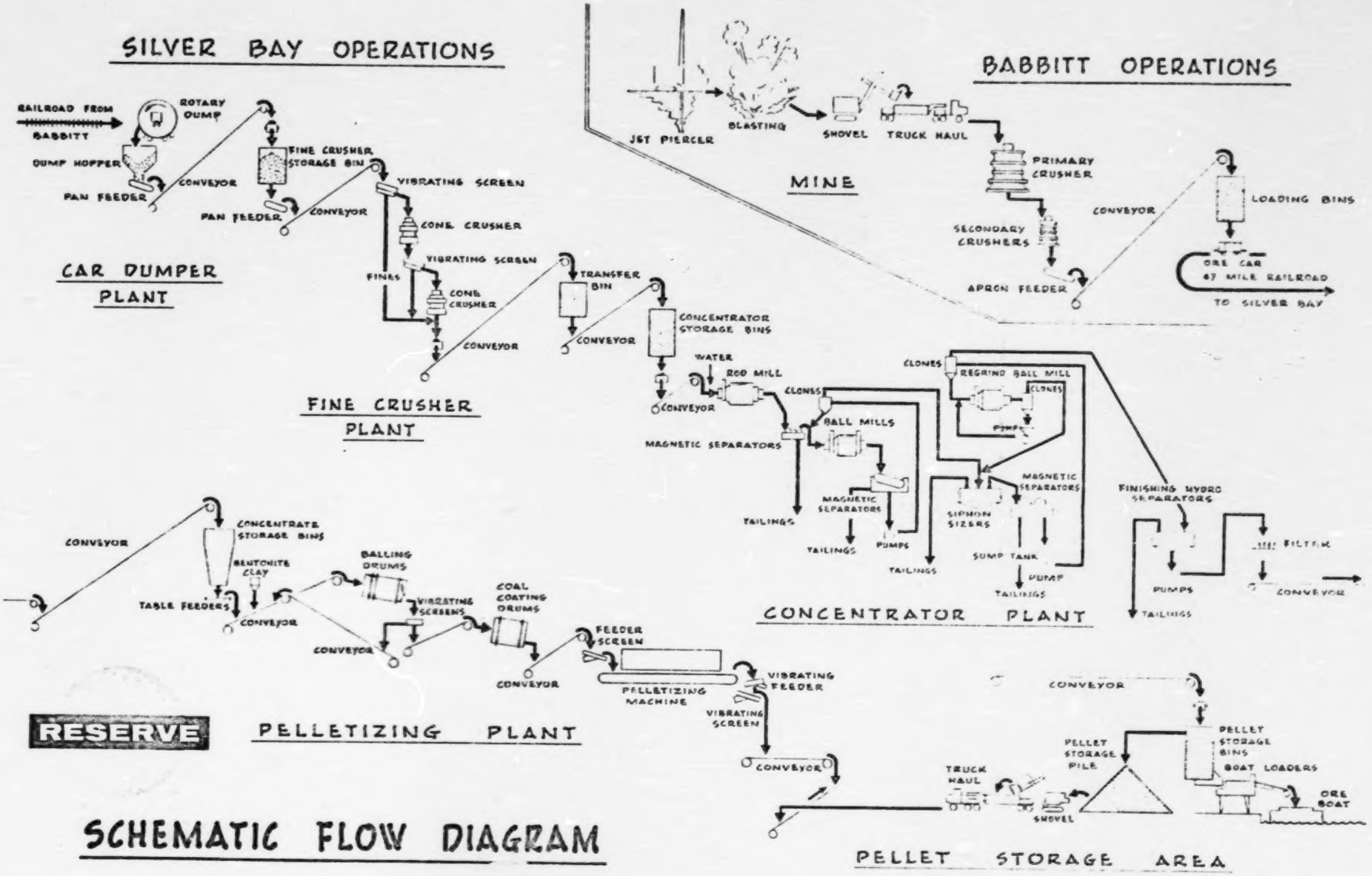
In addition to the full production plant, there is a one-third scale Pilot Plant at the R & D Building, which is equipped with facilities similar to those used in the main processing plant. Operations at the Pilot Plant are interruptible, and the tailings together with wastewater are discharged into the lake through a separate launder.

Reserve Mining currently employs about 3,200 people, approximately evenly divided between the Babbitt Mine and the Silver Bay Plant. Potable water supply at the processing plant is obtained from the town of Silver Bay water supply system Sanitary sewage is to be kept separate from the process wastewaters and is discharged to the community sewer system for treatment at the Silver Bay Sewage Treatment Plant.

### Process Units Related to Wastes Generation

A schematic process flow diagram showing the wet processes employed at the Concentrating Plant is presented in Figure C-1. The function, capacity, and general physical description of each major type of equipment are presented in the following paragraphs.

1. Rod Mills (22 units): There is one Rod Mill in each of the twenty-two sections. Each Rod Mill is 10-1/2 ft. in diameter by 16 ft. long and is driven by an 800-hp motor rotating at a speed of 15 rpm. Capacity of each Rod Mill is 140 to 180 long tons per hour, with an average of about 168 LTPH. Approximately 470 gpm of water is added to each Rod Mill, where crude taconite ore (less than 3/4 inch) is ground to smaller than 20-mesh. Discharge from the Rod Mills is transferred to Cobber Magnetic Separators for separation of waste material.


SILVER BAY OPERATIONS
RAILROAD FROM BABBITT
ROTARY DUMP
DUMP HOPPER
PAN FEEDER
CONVEYOR
FINE CRUSHER STORAGE BIN
PAN FEEDER
CONVEYOR
CAR DUMPER PLANT
VIBRATING SCREEN
CONE CRUSHER
VIBRATING SCREEN
FINES
CONE CRUSHER
CONVEYOR
FINE CRUSHER PLANT
TRANSFER BIN
CONVEYOR
CONCENTRATOR STORAGE BINS
CONVEYOR
WATER
ROD MILL
CLONES
MAGNETIC SEPARATORS
TAILINGS
BALL MILLS
MAGNETIC SEPARATORS
TAILINGS
PUMPS
CLONES
REGRIND BALL MILL
CLONES
PUMP
TAILINGS
SIPHON SIZERS
MAGNETIC SEPARATORS
SUMP TANK
PUMP
TAILINGS
FINISHING HYDRO SEPARATORS
PUMPS
TAILINGS
FILTER
CONVEYOR
CONCENTRATOR PLANT
BABBITT OPERATIONS
JET PIERCER
BLASTING
SHOVEL
TRUCK HAUL
MINE
PRIMARY CRUSHER
SECONDARY CRUSHERS
APRON FEEDER
CONVEYOR
LOADING BINS
ORE CAR
47 MILE RAILROAD
TO SILVER BAY
CONVEYOR
CONCENTRATE STORAGE BINS
BENTONITE CLAY
TABLE FEEDERS
CONVEYOR
BALLING DRUMS
VIBRATING SCREENS
CONVEYOR
COAL COATING DRUMS
CONVEYOR
FEEDER SCREEN
PELLETIZING MACHINE
VIBRATING FEEDER
VIBRATING SCREEN
CONVEYOR
PELLETIZING PLANT
CONVEYOR
PELLET STORAGE BINS
BOAT LOADERS
ORE BOAT
PELLET STORAGE PILE
SHOVEL
TRUCK HAUL
PELLET STORAGE AREA

RESERVE

SCHEMATIC FLOW DIAGRAM

FIGURE C-1

2. Cobber Magnetic Separators (44 units): There are two Cobber Magnetic Separators in each of the twenty-two sections. They are belt-type, two-drum units. A total of about 530 gpm of water is sprayed to each Cobber. Tailings from the Cobbers represent 41 percent of the feed tonnage, or 61 percent of the total tailings from the Concentrating Plant. Wastewaters from all Cobbers represent about 16 percent of the water used at the Concentrating Plant (not including the flushing water used at the main flumes), or 8 percent of total plant usage when considering the flushing water at the main flumes and the West Launder. Particle sizes of the tailings are: 5 percent greater than #3 mesh; 66 percent between #3 mesh and #35 mesh, 6 percent between #35 mesh and #100 mesh; 21 percent between #100 mesh and 5 microns; and 2 percent less than 5 microns. Concentrate from the Cobber Magnetic Separators is transferred to Ball Mills for further grinding.

3. Ball Mills (44 units): There are two Ball Mills in each of the twenty-two sections. Each Ball Mill is 10-1/2 ft. in diameter by 14 ft. long and is driven by an 800-hp synchronous motor rotating at a speed of 16 rpm The Ball Mills receive concentrate from Cobber Magnetic Separators and underflow from Dorrclones. In addition, an average of 73 gpm of water is added to each Ball Mill to maintain the required solids consistency during grinding. The solids are ground to 80 percent passing #325 mesh at the rate of about 50 long tons per hour. Discharge from each Ball Mill is distributed to four Rougher Magnetic Separators for separation of waste material.

4. Rougher Magnetic Separators (172 units): There are eight units of 4-ft. wide Inclined-Belt Rougher Magnetic Separators in each of twenty-one sections (in Section No. 3 there are four units of 10 ft. wide by 3 ft. diameter Rougher Permanent Magnetic Drums). A total of roughly 300 gpm of water is added to each Rougher Magnetic Separator. Tailings from the Separators represent 19 percent of water consumption at the Concentrating Plant or 9.5 percent of total plant consumption including the flushing waters.

   Particle sizes of the tailings are 6 percent greater than #35 mesh; 15 percent between #35 and #100 mesh; 26 percent between #100 and #325 mesh; 44 percent between #325 mesh and 5 microns; and 9 percent smaller than 5 microns. Concentrate from the eight Rougher Magnetic Separators in each section is collected in two sumps, diluted and pumped to two Cyclone Headers, and distributed to eight Dorrclones.

5. Dorrclones (176 units): There are eight Dorrclones (also called Cyclone Classifiers) in each of the twenty-two sections. Overflow from the Dorrclones (53 percent iron with 85 percent of the particles smaller than #325 mesh) flows to Hydroseparators. Underflow from the Dorrclones is returned to the Ball Mills.

6. Hydroseparators (44 units): There are two Hydroseparators (also called Siphon Sizers) in each of the twenty-two sections. Twenty-four of these units, located in the West Sections, are 16 ft. diameter by 8 ft. side water depth; while twenty units, located in the East Sections, are 18 feet in diameter at the top and 16 feet in diameter at a lower section with an 18-foot side water depth.

   These Hydroseparators are of the thickener type. Approximately 470 gpm of water is sprayed to the lower portion of each Hydroseparator to prevent clogging.

Reproduced from best available copy.

The siphon concentrate from the Hydroseparators is fed to Finishing Magnetic Separators, while overflow is wasted as tailings. The wastewater from Hydroseparators represents approximately 24 percent of the water used at the Concentrating Plant and 12 percent of the total plant usage. Tailings from the Hydroseparators represent 7 percent of the crude ore tonnage or 10 percent of the total tailings from the Concentrating Plant. Particle sizes of the tailings are: 14 percent between #150 mesh and #325 mesh; 72 percent between #325 mesh and 5 microns; and 14 percent smaller than 5 microns.

7. Finishing Magnetic Separators (132 units): There are six Finishing Magnetic Separators of the double-drum type in each of the twenty-two sections. The Finishing Magnetic Separators receive siphon concentrate from Hydroseparators. A total of about 410 gpm of water is further sprayed to each Finishing Magnetic Separator. The concentrate (containing 62.5 percent iron) from the six Finishing Magnetic Separators in each section is collected in a sump, where additional water is added, and the slurry is pumped to Primary Cyclones of a Regrind Ball Mill. Wastewater from the Finishing Magnetic Separators represents 24 percent of the Concentrating Plant usage. Tailings from the Separators account for only 4 percent of the total tailings from the Concentrating Plant. Particle sizes of the solids are 50 percent between #100 and #325 mesh; 28 percent between #325 mesh and 5 microns; and 18 percent less than 5 microns.

8. Primary Cyclones (132 units): There are six Primary Cyclones in each of the twenty-two sections. These are used to separate some of the coarser concentrate (from the Finishing Magnetic Separators) for further grinding at the Regrind Ball Mills. Overflows from the Primary Cyclones are forwarded to Finishing Hydroseparators.

9. Regrind Ball Mills (22 units): There is one Regrind Ball Mill in each of the twenty-two sections. Underflows from the Primary Cyclones, as well as returned material from the Secondary Cyclones, are fed to the Regrind Ball Mills. In addition, an average flow of 54 gpm of water is added to each Regrind Ball Mill, where the solids are ground to smaller than #325 mesh, at a rate of about 61 long tons per hour. Discharge from each Regrind Ball Mill is collected at a sump, where an additional 520 gpm of water is added, and the slurry is sent to Secondary Cyclones.

10. Secondary Cyclones (44 units): There are two Secondary Cyclones in each of the twenty-two sections. Secondary Cyclones are used as part of the Regrind Ball Mill operation. These units receive discharge from the Regrind Ball Mills, with the underflow being returned to the same units and the overflow forwarded to the Hydroseparators (i.e. siphon sizers).

11. Finishing Hydroseparators (44 units): There are two Finishing Hydroseparators in each of the twenty-two sections. (Twenty-four units (in the West Sections) are 14 feet in diameter by 6-1/2 feet side water depth, and twenty units (in the East Sections) are 16 feet in diameter by 6-1/2 feet side water depth. These units serve as thickeners, having overflow rates ranging from 6,000 to 8,000 gpd/sq.ft.

Underflows from the Finishing Hydroseparators are pumped to Disc Vacuum Filters for dewatering, and overflows are wasted to the main flumes. Wastewater from the Finishing Hydroseparators amounts to 18 percent of the water usage at the Concentrating Plant. As a contrast, tailings from the Finishing Hydroseparators account for only 0.5 percent of total tailings from the Concentrating Plant. Particle sizes of the tailings in the overflow from the Finishing Hydroseparators are mostly within the size range of less than #325 mesh to 5 microns.

12. Disc Vacuum Filters (22 units): There is one disc-type vacuum filter in each of the twenty-two sections. Underflow from the Finishing Hydroseparators (containing approximately 50 percent solids) is dewatered at the Vacuum Filters to yield a concentrate of approximately 10 percent moisture. Filtrate from the Vacuum Filters is returned to the Finishing Hydroseparators. The dewatered concentrate is transferred to the Pelletizer Plant by a conveyor.

13. Pelletizer Plant Thickener (1 unit): The Pelletizer Plant Thickener is located outside the west end of the Concentrating Plant. It receives 5,100 gpm of wastewater (i.e. 1.2 percent of total plant water usage) from the Pelletizer Plant and discharges the overflow to the west end of the west main flume inside the Concentrating Plant near Section No. 12.

14. Dust Collectors at Fine Crushers: A total of 2,000 gpm of water is used at the Fine Crusher dust collectors. The wastewater is discharged to the west main flume inside the Concentrating Plant near Section No. 1.

15. Power Plants: An average of 500 gpm of wastewater from the water treatment facilities at the Power Plant is discharged directly to the West Launder outside the Concentrating Plant building.

16. Pilot Plants: There is a one-third scale pilot plant at the Research and Development Building. Operations at the Pilot Plant are intermittent. When in operation, wastewaters are estimated to average 3,000 gpm containing 900 long tons per day of tailings which are discharged directly into the lake through a separate launder.

### Flushing Water Used at Main Flumes and West Launder

A total of 26,500 gpm of water is added to the East Main Flume in the east side of the Concentrating Plant, at four locations near Section Nos. 101, 102, 108, and 109, to help flush the solids and to prevent deposits. Also, a flow of 51,300 gpm of water is added to the West Main Flume in the west side of the Concentrating Plant at three locations near Section Nos. 4, 11, and 12, for the same purpose.

In addition, 120,000 gpm of flushing water is added to the mid-section of the West Launder outside the Concentrating Plant. All of these flushing waters add up to almost 200,000 gpm, or 48 percent of the total water usage for the entire plant. If the coarse tailings from the Cobber Magnetic Separators are segregated at the source, it is quite likely that the water used for flushing purposes at the flumes and at the West Launder may be totally eliminated or greatly reduced.

### Effect of Calcium Chloride Usage

Calcium chloride is used at both Babbitt and Silver Bay to prevent freezing of taconite ore. It has been reported that purchases of calcium chloride range from about 600 to 800 tons per month during the winter. Some of the calcium chloride is also used to prevent icing on roads, in fire barrels, and around buildings.

During February 1970, approximately 500 tons of calcium chloride (0.22 pound per ton of crude ore) were used at Babbitt and 45 tons of calcium chloride (less than 0.02 pound per ton of crude ore) at Silver Bay. Reserve Mining personnel estimated that calcium chloride usage per ton of crude ore may exceed 0.3 pound for short periods of -30°F weather, but that 0.3 would certainly be the highest average value for any winter month.

Based on maximum calcium chloride usage of 0.3 pound per ton, average crude ore production of 88,600 long tons per day, and total average water usage of 414,000 gpm, the incremental concentrations would be 5.4 mg/L as $CaCL_2$ or 1.9 mg/L as Ca, assuming that most of the calcium chloride is dissolved in the water phase and little is retained in the iron pellet product.

Calcium increase between intake and launder discharge for samples taken on March 5 and 6, 1970 showed an average increase of 2.28 mg/L as Ca, thus providing a reasonable check for the above estimate.

One concern expressed by Reserve Mining personnel is that build-up of calcium chloride concentration in a water recycle system would interfere in the pelletizing operation. The maximum allowable limit of calcium chloride concentration has not been established, but it is desirable to keep the calcium chloride content of the final iron concentrate low. If a water recycling system is to be used for the Concentrating Plant, the $CaCl_2$ content can be controlled by counter-current type of water usage or by the use of fresh make-up water at or prior to the vacuum filter dewatering operation.

### Summary of Water Usage, Tailings, and Wastewater Quantities

A process flow diagram showing the locations of water usage, tailings and wastewater generating sources, as well as their average quantities, is shown on Figure C-2. A summary of water usage for the total plant indicating the specific locations of water addition is tabulated in Table C-1. Another summary of tailings and wastewater quantities for the five major sections of the plant (Cobber Magnetic Separators, Rougher Magnetic Separators, Hydroseparators, Finishing Magnetic Separators, and Finishing Hydroseparators) is presented in Table C-2. Also, a summary of particle size analyses of tailings is given in Table C-3. The flow diagram and tables are in sufficient detail to be self-explanatory.

## Erie Mining Company

### General

The Erie Mining Company is managed by a division of the Diamond Shamrock Corporation. The three main divisions of Diamond Shamrock are the Diamond Alkali Chemical Division, the Shamrock Oil Division, and Pickands Mather Mining Division which includes Erie Miming Company. Erie Mining is managed by Pickands Mather and owned 45 percent by Bethlehem Steel Corporation, 35 percent by Youngstown Sheet and Tube, 10 percent by Steel Company of Canada, and 10 percent by Interlake, Inc.

EXISTING SOLIDS AND WATER BALANCE FOR TOTAL PLANT (1967-71 AVERAGE) - RESERVE MINING COMPANY

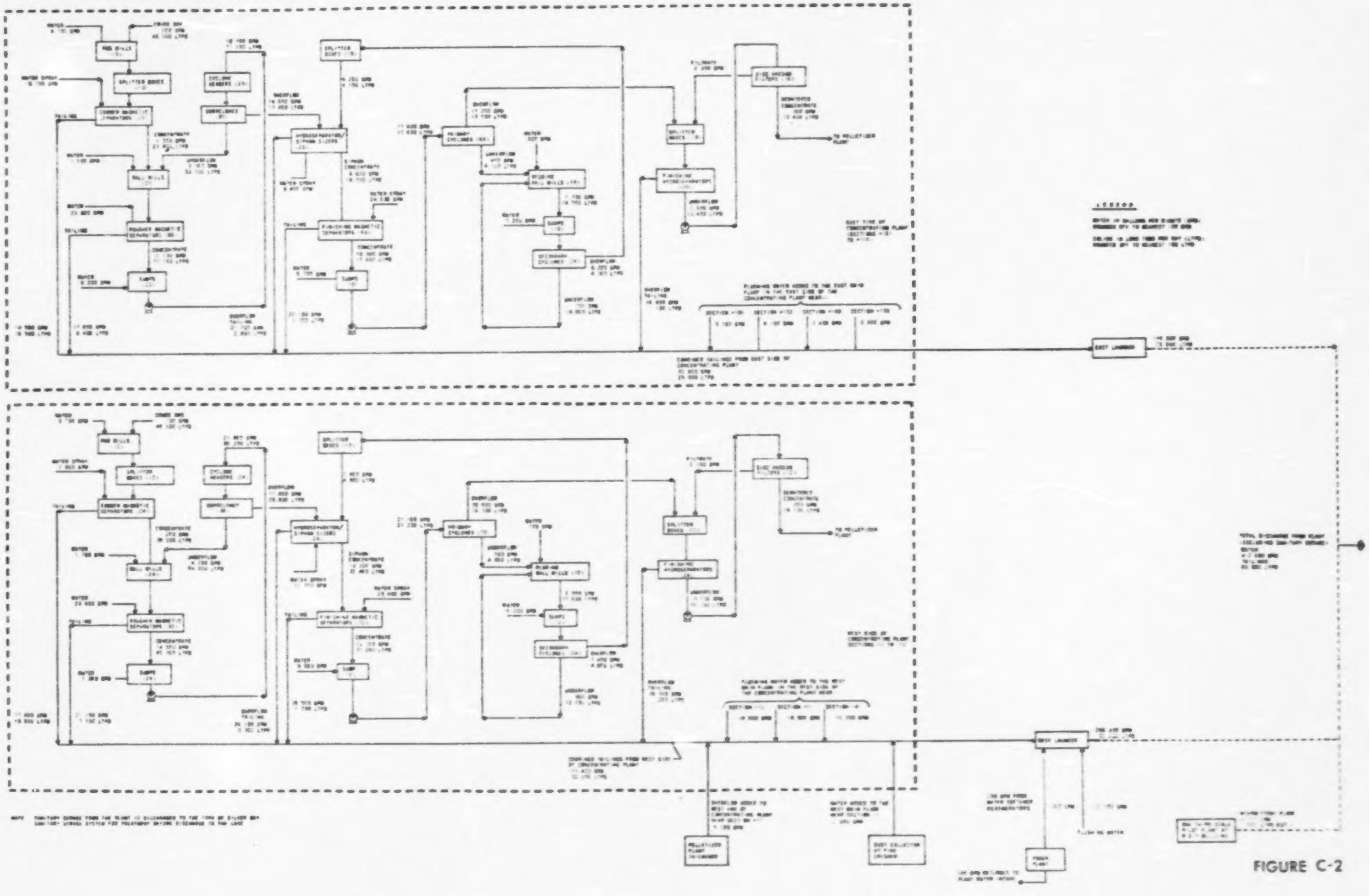


FIGURE C-2

## Table C-1

Reserve Mining Company
Silver Bay, Minnesota

Summary of Water Usage (1967-71 Average)

| | | Flow in gpm | |
|---|---|---|---|
| A. | Process Water Used at Concentrating Plant | | |
| 1. | Water added to twenty-two (22) Rod Mills | 10,400 | |
| 2. | Spray Water to forty-four (44) Cobber Magnetic Separators | 23,500 | |
| 3. | Water added to forty-four (44) Ball Mills | 3,200 | |
| 4. | Water added to one hundred and seventy-two (172) Rougher Magnetic Separators | 52,400 | |
| 5. | Water added forty-four (44) sumps at Rougher Magnetic Separators | 13,200 | |
| 6. | Spray water to forty-four (44) Hydroseparators (also called Siphon Sizers) | 20,700 | |
| 7. | Spray water to one hundred and thirty-two (132) Finishing Magnetic Separators | 53,900 | |
| 8. | Water added to twenty-two (22) Sumps at Finishing Magnetic Separators | 14,700 | |
| 9. | Water added to twenty-two (22) Regrind Ball Mills | 1,200 | |
| 10. | Water added to twenty-two (22) Sumps at Regrind Ball Mills | 11,400 | |
| | Sub-Total | | 204,600 |
| B. | Flushing Water Added to the East Main Flume (Inside the Concentrating Plant Building) | | |
| 1. | Near Section No. 101 | 6,100 | |
| 2. | Near Section No. 102 | 6,100 | |
| 3. | Near Section No. 108 | 7,400 | |
| 4. | Near Section No. 109 | 6,900 | |
| | Sub-Total | | 26,500 |
| C. | Flushing Water Added to the West Main Flume (Inside the Concentrating Plant Building) | | |
| 1. | Near Section No. 4 | 15,300 | |
| 2. | Near Section No. 11 | 18,000 | |
| 3. | Near Section No. 12 | 18,000 | |
| | Sub-Total | | 51,300 |
| D. | Flushing Water Added to the West Launder (Outside the Concentrating Plant Building) | | 120,000 |
| 1. | Power Plant | 500 | |
| 2. | Pelletizer Plant Thickener | 5,100 | |
| 3. | Spray on Pellet Storage Pile (lost as evaporation) | 500 | |
| 4. | Dust Collector Water used at Fine Crusher | 2,000 | |
| 5. | One-third scale Pilot Plant at R & D Building | 3,000 | |
| 6. | Moisture loss at Pelletizer | 700 | |
| 7. | Moisture contained in Crude Oil | (-200) | |
| | Sub-Total | | 11,600 |
| | TOTAL PLANT INTAKE | | 414,000 gpm<br>(or 596.2 mgd) |

Table C-2

Reserve Mining Company
Silver Bay, Minnesota

Summary of Tailings and Wastewater Quantities (1967-71 Average)

| Item | Cobber Magnetic Separators | Rougher Magnetic Separators | Hydro-Separators (Siphon Sizers) | Finishing Magnetic Separators | Finishing Hydro-Separators | Others (Mostly Flushing Waters) | Total |
|---|---|---|---|---|---|---|---|
| A. East Side of Concentrating Plant (Ten Sections) | | | | | | | |
| Tailings, LTPD | 16,500 | 6,400 | 2,800 | 1,100 | 100 | -- | 26,900 |
| Wastewaters (Prior to Addition of Flushing Waters), gpm | 14,500 | 17,600 | 21,700 | 22,100 | 16,900 | -- | 92,800 |
| Percent (by weight) of Solids in Slurry (Prior to Addition of Flushing Waters) | 17.5 | 6.3 | 2.4 | 0.9 | 0.1 | -- | 5.1 |
| Flushing Waters (Inside Concentrating Plant Bldg.), gpm | -- | -- | -- | -- | -- | 26,500 | 26,500 |
| Combined Wastewaters and Flushing Waters (at East Launder), gpm | -- | -- | -- | -- | -- | -- | 119,300 |
| Percent (by weight) of Solids in Slurry (at East Launder) | -- | -- | -- | -- | -- | -- | 4.0 |
| B. West Side of Concentrating Plant (Twelve Sections) | | | | | | | |
| Tailings, LTPD | 19,800 | 7,700 | 3,300 | 1,200 | 200 | -- | 32,200 |
| Wastewaters (Prior to Addition of Flushing Waters), gpm | 17,400 | 21,100 | 26,100 | 26,500 | 20,300 | -- | 111,400 |
| Percent (by weight) of Solids in Slurry (Prior to Addition of Flushing Waters) | 17.5 | 6.3 | 2.4 | 0.9 | 0.1 | -- | 5.1 |
| Flushing Waters (Inside Concentrating Plant) Plus Wastewaters from Pelletizer Plant and Fine Crusher, gpm | -- | -- | -- | -- | -- | 58,400 | 58,400 |
| Flushing Water at West Launder (Outside Concentrating Plant) Plus Wastewater from Power Plant, gpm | -- | -- | -- | -- | -- | 120,500 | 120,500 |
| Combined Wastewaters and Flushing Waters (at West Launder), gpm | -- | -- | -- | -- | -- | -- | 290,300 |
| Percent (by weight) of Solids in Slurry (at West Launder) | -- | -- | -- | -- | -- | -- | 2.0 |
| C. Pilot Plant (One-third Scale) at R & D Bldg. | | | | | | | |
| Tailings, LTPD | 560 | 210 | 90 | 40 | 4 | -- | 900 |
| Wastewaters, gpm | 500 | 600 | 700 | 700 | 500 | -- | 3,000 |
| PLANT TOTAL | | | | | | | |
| Tailings, LTPD | 36,900 | 14,300 | 6,200 | 2,300 | 300 | -- | 60,000 |
| Percent of Total Tailings | 61.4 | 23.9 | 10.3 | 3.9 | 0.5 | -- | 100 |
| Wastewaters, gpm | 32,400 | 39,300 | 48,500 | 49,300 | 37,700 | 205,400 | 412,600 |
| mgd | 46.7 | 56.6 | 69.8 | 71.0 | 54.2 | 295.8 | 594.1 |
| Percent of Total Wastewaters | 7.9 | 9.5 | 11.8 | 11.9 | 9.1 | 49.8 | 100 |
| Gallons of Water Per Long Ton of Tailings, GPLT | 1,270 | 3,960 | 11,300 | 30,900 | 180,000 | -- | 9,900 |
| Percent (by weight) of Solids in Slurry | 17.5 | 6.3 | 2.4 | 0.9 | 0.1 | -- | 2.8 |

## Table C-3

Reserve Mining Company
Silver Bay, Minnesota

### Particle Size Analysis of Tailings from Concentrating Plant

| Mesh Size (Tyler Sieve Series) | Sieve Opening microns | Percent By Weight Passing the Indicated Sieve Size: Cobber Magnetic Separators | Rougher Magnetic Separators | Hydro-Separators (Siphon Sizers) | Finishing Magnetic Separators | Finishing Hydro-Separators | Total Tailings |
|---|---|---|---|---|---|---|---|
| 3 | 6,730 | 94.7 | | | | | 96.7 |
| 4 | 4,760 | 84.6 | | | | | 90.3 |
| 6 | 3,360 | 70.7 | | | | | 81.6 |
| 8 | 2,380 | 56.4 | 100 | | | | 72.7 |
| 10 | 1,680 | 48.6 | 97.0 | | | | 67.0 |
| 14 | 1,190 | 40.4 | 96.3 | | | | 61.6 |
| 20 | 841 | 34.1 | 95.6 | | | | 57.4 |
| 28 | 595 | 31.3 | 94.8 | | | | 55.5 |
| 35 | 420 | 29.0 | 93.3 | | | | 53.7 |
| 48 | 297 | 27.4 | 90.3 | | | | 51.9 |
| 65 | 210 | 25.6 | 85.6 | | 100 | | 49.5 |
| 100 | 140 | 23.1 | 78.8 | | 96.5 | | 46.0 |
| 150 | 105 | 21.2 | 69.9 | 100 | 75.0 | | 41.7 |
| 200 | 74 | 19.3 | 63.2 | 97.2 | 57.2 | | 38.0 |
| 270 | 53 | 18.3 | 55.8 | 91.7 | 50.0 | | 34.9 |
| 325 | 45 | 16.8 | 52.8 | 86.2 | 46.4 | 100 | 32.5 |
| | 30 | 12.0 | 41.3 | 68.1 | 39.3 | 50 | 24.8 |
| | 20 | 8.6 | 31.2 | 50.0 | 32.2 | 50 | 18.5 |
| | 10 | 4.1 | 15.6 | 23.6 | 25.0 | <0.05 | 9.2 |
| | 5 | 2.2 | 8.9 | 13.9 | 17.9 | <0.05 | 5.3 |

## Description of Concentrating Operations

The Erie Mining Company ore-concentrating facilities shown in Figure C-3 are designed to achieve a production rate of 10.3 million tons of pellets annually. This requires the delivery of approximately 31 million tons of ore per year to the processing facility, or an average of 85,000 tons of ore for a 24-hour day.

This ore is mined in several different areas extending from approximately 6.6 miles west of the ore course-crushing facility to 20 miles northeast. The ore is delivered by rail cars to the coarse crusher located adjacent to the concentrating plant. Following coarse crushing, the ore is transported by belt conveyors to a fine-crushing operation and then to the concentrating process. The fine-crushed ore, approximately 3/16" maximum size, is capable of handling 100,000 tone of ore each day and contains 36 separate but similar mill lines. Each mill line treats approximately 120 tons of feed each hours. Each mill line consists of:

1. One 12'2" x 4' rod mill driven by an 800-hp motor.
2. One 5' x 8' vibrating screen.
3. Two 3' diameter by 4' wide double drum electromagnetic separators (first or rougher stage of concentration).
4. One 12' 2" x 14' grate ball mill driven by a 1250-hp motor and operating in a closed circuit with four 3'-diameter by 5'-wide single-drum permanent magnet cleaner separators, and five 14" classifying cyclones.
5. Four 3'-diameter by 5'-wide single-drum permanent magnet cleaner separators.
6. Four 2-1/2'-diameter by 5'-wide triple-drum permanent magnet finisher separators.

Each pair of mill lines shares a set of primary and secondary screens, which are used to separate the overhead from the coarse-grind cyclones. The fines from this overhead are returned to the finishing magnets. The coarse fraction of the screenings is returned to the ball mill for refinishing. The concentrate from the finishers is pumped to banks of fine screens to remove the +325 mesh portion for further concentration by regrind and magnetic separation. The regrind material is screened and the fines are delivered to the concentrate thickener, equipped with siphons to remove the product. The concentrate is then dewatered by magnetic separators and pumped 2,500 feet to the pelletizing plant.

## Description of Pelletizer Operations

The concentrator slurry at 42-50 percent solids is discharged into a central collecting sump at the pellet plant and mixed with reprocessed dust-collector residue, reground furnace fines, and recirculated concentrates from the slurry blending and storage tank system. This material is then pumped to one of fourteen concentrate thickeners for dewatering. These 40'-diameter concentrate thickeners receive the slurry at 45 percent solids and discharge it at 72 percent solids. The concentrated slurry is dewatered by vacuum disc filters. Fifty-five units are installed, of which fifty-one are of the eight-disc type and four are of a five-disc type. These filters reduce the moisture in the concentrate to a level of 9-1/2 to 10-1/2 percent.

The dewatered concentrate is delivered to balling drums and then to pelletizing furnaces. The pelletizing plant is provided with a regrind system for the undersized or damaged pellets. The water used in this process is concentrated in a fines circuit thickener, with the overflow water being returned to the main plant thickeners.

# CONCENTRATOR FLOWSHEET

ERIE MINING COMPANY

**CONVENTIONAL MILL LINE** | **CLOSED CIRCUIT SCREENING** | **REGRIND SCREENING**

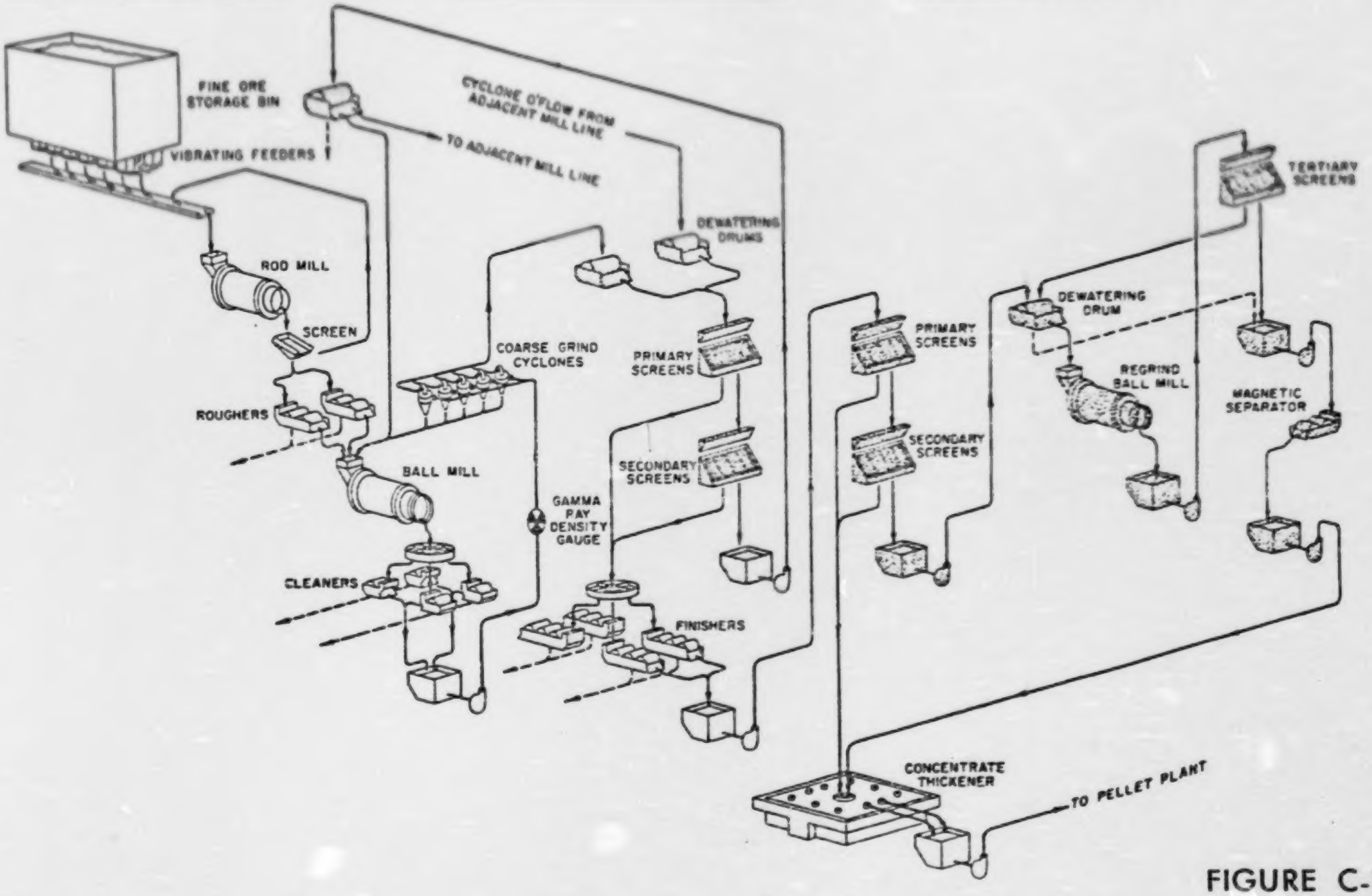

FINE ORE STORAGE BIN
VIBRATING FEEDERS
ROD MILL
SCREEN
ROUGHERS
BALL MILL
CLEANERS
CYCLONE O'FLOW FROM ADJACENT MILL LINE
TO ADJACENT MILL LINE
COARSE GRIND CYCLONES
GAMMA RAY DENSITY GAUGE
DEWATERING DRUMS
PRIMARY SCREENS
SECONDARY SCREENS
FINISHERS
PRIMARY SCREENS
SECONDARY SCREENS
DEWATERING DRUM
REGRIND BALL MILL
TERTIARY SCREENS
MAGNETIC SEPARATOR
CONCENTRATE THICKENER
TO PELLET PLANT

FIGURE C-3

## Description of Plant Tailings System

Tailing material from the first and second steps of magnetic separation of each group of four mill lines is combined and flows to a hydroseparator for removal of the coarse fraction. This coarse underflow fraction is discharged directly to the tailing basin. The overflow from the nine hydroseparators and the tailings from the finishers flow into five 255'-diameter tailing thickeners. The underflow from the tailing thickener is combined with the underflow from the hydroseparator for discharge to the tailing basins. The material discharged to the tailing basins is reported to contain approximately 40 percent solids. The water flow rate in the plant is reported as approximately 141,300 gallons per minute (gpm) as tabulated below:

111,700 gpm returned from thickeners
22,500 gpm returned as barge water from the tailing basin
7,100 gpm obtained as makeup from the plant reservoir, which is supplied from Colby Lake

This total flow of 141,300 gpm includes the plant requirements of 300 gpm for potable water. The approximate breakdown of water consumption at loss (which brings on the need for makeup water) is as follows:

600 gpm vapor loss from pelletizer furnaces
600 gpm car watering (quench cooling)
100 gpm cooling on belt conveyors to stockpile
2,800 gpm tailing basin loss (seepage, evaporation and retained in beds)
300 gpm domestic water usage
500 gpm air conditioning cooling requirements
2,200 gpm unaccounted for (presumably used for washdown water, etc.)

Makeup water is obtained through a 30" line from Colby Lake at pumping rates of up to 12,000 gpm. The first addition of water to the ore is made in the rod mills. The pH of makeup water varies from 6 to 8, while the pH of the reclaim barge water from the tailings basin ranges from 8 to 8.2. The plant has two main tailing basins: The No. 1 Basin covers 1,300 acres, of which approximately 500 are under water; the No. 2 Basin covers 700 acres, of which approximately 250 are under water. The basin dikes are created by bulldozing the tailings from the inside edge of the basin up to the top of the dikes.

It should be noted that this bulldozing operation, although intended to bring up coarse tailings which should settle near the edge of the lake, also brings fine tailings to the top of the dike, which on occasions become windblown and of severe nuisance value. The water is discharged into the tailings basin by pipeline systems which encircle the tailing ponds at the top of the dikes. These lines are moved as the elevations of the dikes are changed. There are approximately 14 discharge lines from the main tailings pumphouse which reach out to circle the two tailing basins. At necessary locations, additional booster pumps are installed to maintain the pressure and velocity in the tailings slurry lines. These lines are nominally 12 to 14 inches in diameter, with flow velocities ranging from 12 to 15 feet per second.

Water flow to the pellet plant consists primarily of makeup water from the reservoir, plus small quantities of recirculated water from the overflow of the tailings thickener. All water is supplied to the plant through a loop system however, the plant makeup water is added at or near the branch line to the pellet plant so that the pellet plant receives the cleanest water. This clean water is required for the chunk breakers at the bottom of the pellet furnaces to prevent the development of encrustations in the chunk breaker cooling water lines.

Of the estimated 10,000 gpm delivered to the pellet plant, approximately 5,670 gpm go to the chunk breakers and the remaining 4,330 gpm go to the filter dilution and dust collection systems.

The size and number of thickeners in the plant is as follows:

Nine 18'-diameter hydroseparators
Fourteen 50'-diameter concentrate thickeners
One 125'-diameter fines circuit thickener
Five 255'-diameter tailings thickeners
Nine 25'-square siphon sizers

The plant also contains four 20,000-gallon head tanks on the circulating water system.

Samples for laboratory analysis were obtained during the morning of June 2nd from the No. 1 North hydroseparator overflow, the tailings thickener overflow, reservoir water from Colby Lake, the overflow from the fines circuit thickener at the pellet plant, the influent to the tailings basin from the first booster pumphouse, a sample of barge water from a nozzle at the barge, a sample of water being pumped from the lower basin (which possibly might be seepage from the upper basin), and a dry sample of combined tailings prepared by the Erie laboratory. The results of these analyses performed by ROY F. WESTON on these samples are shown in Table C-4.

### Material Balance

Data received from the plant were used to prepare an ore and water material balance. This ore and water balance was then sent to Erie for their review and comment. Their input is included in the balance shown in Figure C-4. This balance indicates a lower flow from the tailings thickener and a higher flow of barge water than reported in the plant records. This is possibly due to our assumption of 45% solids in the thickener tailings.

## Eveleth Taconite Company

### General

The ore concentrating facilities of the Eveleth Taconite Company near Forbes, Minnesota was visited by ROY F. WESTON personnel on June 2nd and 3rd, 1971.

All flow data for this plant was received in verbal form Much of the information received was based on the memory of plant personnel, and the randomness of the numbers presented caused appreciable difficulty in obtaining a reasonable material balance.

### Description of Concentrating Operations

The Eveleth ore crushing, concentrating, and pelletizing facilities shown in Figure C-5 were designed to achieve a production rate of 1.6 million tons of pellets per year. This production rate has increased to an estimated 1970 production of 2,000,000 tons or product.

## Table C-4

### Analytical Results of Samples from Erie Mining Company

| Sample | pH | Alkalinity mg/l | Acidity mg/l | SS mg/l | DS mg/l | COD mg/l | Cl mg/l | $SO_4$ mg/l | F mg/l | $SiO_2$ mg/l | Fe mg/l | Mn mg/l | Ca mg/l | Mg mg/l | Cu mg/l | Zn mg/l | Cr mg/l | As mg/l | Hg µg/l | Ag mg/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North Hydroseparator Overflow | 7.6 | 1,780 | 10 | 45,150 | 434 | | | | | | | | | | | | | | | |
| Tailings Thickener Overflow | 7.7 | 140 | 12 | 154 | 352 | | 37.8 | | | | | | 18.4 | | | | <0.05 | | | |
| Colby Lake Water from Reservoir | 6.3 | 20 | 14 | 4 | 138 | | 4.4 | 24.8 | 0.33 | <0.2 | 0.63 | <0.05 | 3.1 | 3.8 | 0.095 | 0.10 | 0.05 | <0.2 | 6.9 | <0.05 |
| Pellet Fine Circuit Thickener Overflow | 7.3 | 114 | 10 | 428 | 322 | 19 | 30.2 | 76 | 1.10 | <0.2 | <0.2 | <0.05 | 17.2 | 20 | 0.074 | 0.10 | <0.05 | 0.2 | 0.9 | <0.05 |
| Influent to Tailing Basin | 8.0 | 8,600 | 20 | 516,000 | | 4,570 | 41.4 | 62 | 2.20 | 15.2 | 1.94 | 0.32 | 15.2 | 28 | 0.106 | 0.13 | <0.05 | 1.1 | 3.0 | <0.05 |
| Barge Water | 7.6 | 130 | 8 | 4 | 280 | <5 | 34.8 | 70 | 0.39 | 7.5 | 0.47 | 0.05 | 16.5 | 23 | 0.78 | 0.13 | <0.05 | 0.5 | 2.6 | 0.08 |
| Return from Lower Basin | 7.9 | 140 | 12 | 468 | 266 | 38 | 35 | | | | | | | | | | | | | |
| Combined Railings Dry Sample | | | | | | | 2.5 | <1 | 0 | 0.7 | 0.35 | 0.21 | 2.5 | 0.9 | 0.65 | 0.58 | 0.06 | 0.9 | 0.4 | 0.05 |

NOTE: All samples were filtered through 0.45 micron millipore filter for metals analyses. 1 gram sample (dry weight) leached in 1 L water for 1 hour. Analysis done on leachate.
Samples taken June 2, 1971, except Combined Tailings Dry Sample, which was prepared from samples taken June 1, 1971.

# EXISTING SOLIDS AND WATER BALANCE FOR
# ERIE MINING COMPANY'S TACONITE ORE BENEFICATION PLANT

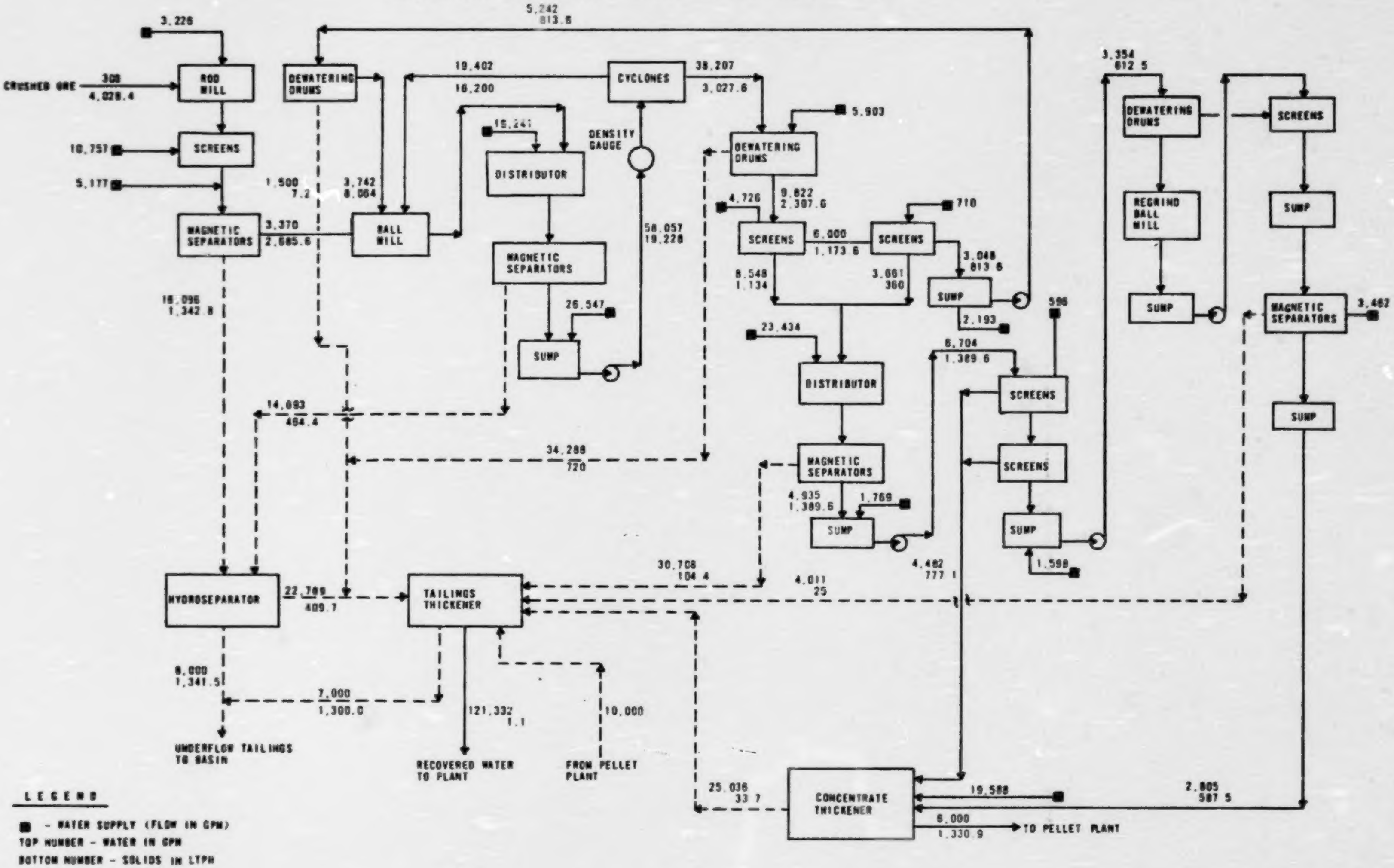
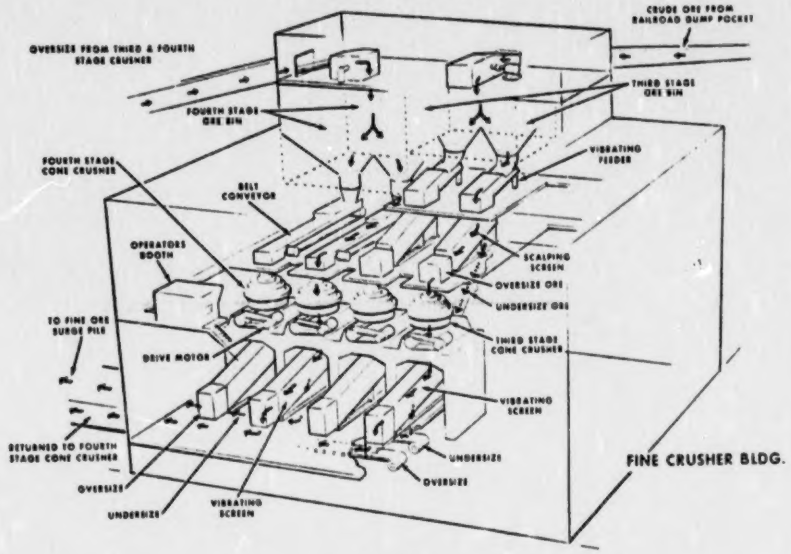
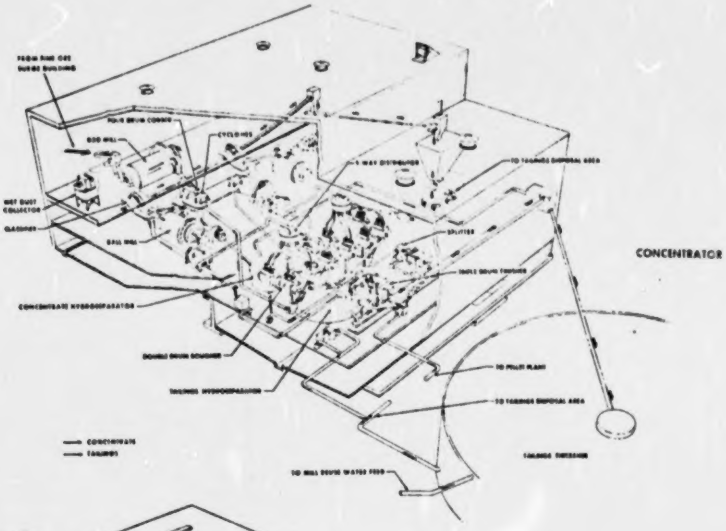

CRUSHED ORE
308
4,028.4
3,228
ROD MILL
SCREENS
10,757
5,177
MAGNETIC SEPARATORS
3,370
2,685.6
16,096
1,342.8
1,500
7.2
3,742
8,064
BALL MILL
DEWATERING DRUMS
5,242
813.8
19,402
16,200
15,241
DISTRIBUTOR
MAGNETIC SEPARATORS
26,547
SUMP
CYCLONES
DENSITY GAUGE
58,057
19,228
38,207
3,027.6
14,693
464.4
34,288
720
DEWATERING DRUMS
5,903
9,822
2,307.6
4,726
SCREENS
6,000
1,173.6
SCREENS
710
8,548
1,134
3,081
380
3,048
813.6
SUMP
2,193
23,434
DISTRIBUTOR
MAGNETIC SEPARATORS
4,935
1,389.6
1,769
SUMP
8,704
1,389.6
4,482
777.1
SCREENS
596
SCREENS
SUMP
1,598
3,354
612.5
DEWATERING DRUMS
REGRIND BALL MILL
SUMP
SCREENS
SUMP
MAGNETIC SEPARATORS
3,482
SUMP
HYDROSEPARATOR
22,709
409.7
TAILINGS THICKENER
30,708
104.4
4,011
25
8,000
1,341.5
7,000
1,300.0
121,332
1.1
10,000
UNDERFLOW TAILINGS TO BASIN
RECOVERED WATER TO PLANT
FROM PELLET PLANT
25,036
33.7
CONCENTRATE THICKENER
19,588
2,805
587.5
6,000
1,330.9
TO PELLET PLANT
LEGEND
■ - WATER SUPPLY (FLOW IN GPM)
TOP NUMBER - WATER IN GPM
BOTTOM NUMBER - SOLIDS IN LTPH

FIGURE C-4

## EVELETH TACONITE COMPANY

## FAIRLANE FACILITIES


CRUDE ORE FROM RAILROAD DUMP POCKET
OVERSIZE FROM THIRD & FOURTH STAGE CRUSHER
THIRD STAGE ORE BIN
FOURTH STAGE ORE BIN
VIBRATING FEEDER
FOURTH STAGE CONE CRUSHER
BELT CONVEYOR
OPERATORS BOOTH
SCALPING SCREEN
OVERSIZE ORE
UNDERSIZE ORE
TO FINE ORE SURGE PILE
THIRD STAGE CONE CRUSHER
DRIVE MOTOR
VIBRATING SCREEN
RETURNED TO FOURTH STAGE CONE CRUSHER
UNDERSIZE
OVERSIZE
FINE CRUSHER BLDG.
OVERSIZE
UNDERSIZE
VIBRATING SCREEN


FROM FINE ORE SURGE BUILDING
FOUR DRUM COBBER
ROD MILL
CYCLONES
5 WAY DISTRIBUTOR
TO TAILINGS DISPOSAL AREA
WET DUST COLLECTOR
CLASSIFIER
BALL MILL
SPLITTER
CONCENTRATOR
TRIPLE DRUM FINISHER
CONCENTRATE HYDROSEPARATOR
DOUBLE DRUM ROUGHER
TO PELLET PLANT
TAILINGS HYDROSEPARATOR
TO TAILINGS DISPOSAL AREA
CONCENTRATE
TAILINGS
TAILINGS THICKENER
TO MILL DRUM WATER FEED

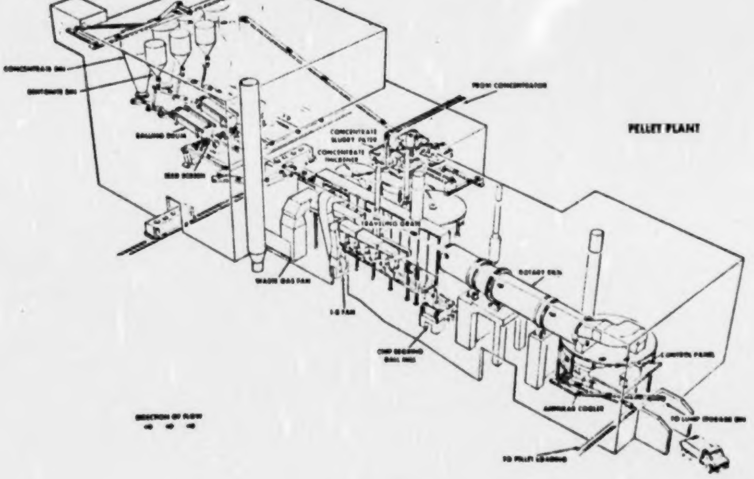

CONCENTRATE BIN
BENTONITE BIN
FROM CONCENTRATOR
PELLET PLANT
BALLING DRUM
CONCENTRATE SLURRY FILTER
CONCENTRATE THICKENER
ROD SCREEN
TRAVELING GRATE
WASTE GAS FAN
ROTARY KILN
I-D FAN
CHIP REGRIND BALL MILL
CONTROL PANEL
ANNULAR COOLER
TO LUMP STORAGE BIN
DIRECTION OF FLOW
TO PELLET LOADING

FIGURE C-5

The ore is mined near Eveleth, approximately ten miles north of the plant. and shipped by common carrier at the rate of approximately 20,000 tons per day, using four trains each day on a five-day per week schedule. The ore is transported in hopper-bottom cars. These cars are unloaded in a shed capable of accommodating twelve cars. The ability to discharge this ore from hopper-bottom cars without the use of calcium chloride to prevent freezing is a point of major interest.

Final crushing of the ore is completed at the plant, following which the ore goes into storage or is delivered into the concentrating facilities. The concentrating facilities are operated seven days per week. The facilities contain two lines. Each line consists of:

1. One 14' x 20' rod mill driven by a 2,000-hp motor.
2. Two 3' x 7' magnetic drum Cobbers.
3. Two 14' x 22' ball mills driven by 2,000-hp motors.
4. A five-way distributor feeding five 3' x 7' double-drum Rougher Magnetic Separators.
5. Feed pump to a 25' x 10' concentrate hydroseparator through six 10" cyclone classifiers.
6. Pump to fine screening.
7. Two 3' x 7' triple-drum finishing magnetic separators.

The screens were not part of the original facilities and have been added to improve the operation. The coarse discharge from the screens returns to the Ball Mill by way of dewatering magnets.

### Description of Pelletizer Operation

The concentrator slurry is pumped to the Pelletizing Plant and received in a pair of Concentrate Thickeners. The concentrate is then pumped to four vacuum disc filters. The dewatered concentrate is transported by belt conveyors to three concentrate bins. then discharged through conveyors into the balling drums, over a speed screen, and eventually transported into a traveling-grate furnace. The pellets are pre-dried on the traveling grate and then discharged into a rotary kiln, where they are fired at a temperature of 2300°F. The discharge from the kiln goes to a rotary cooler, with the completed pellets discharged to shipping facilities.

### Description of Plant Tailings System

The tailings system at Eveleth works on a closed loop, with no discharge of water into the adjacent stream. Makeup water as required by the plant is obtained from a pumping station located on the bank of the St. Louis River, north of the concentrating facilities. The plant is located on an 8,000-acre site, of which approximately 800 acres are enclosed for a tailings discharge area.

This plant differs from the Erie Mining facility in the method of separating a coarse tailings. The coarse tailings from the Cobbing magnets are discharged to a spiral classifier. The plant contains two 66"-diameter spiral classifiers. which discharge the coarse tailings to a 30" belt. The belts convey these tailings (at approximately 17 to 20 percent water) to a 300-ton reject storage bin. The coarse tailings are unloaded from the reject bin into heated-body 50-ton trucks and are hauled approximately one-half mile to the tailings pond for dike construction. The classifiers are sized for a 65-mesh separation.

The balance of water from the spiral classifier and the fine tailings are transported to a tailings hydroseparator, with the underflow discharged to the tailings pond. The overflow from the hydroseparator is discharged to a tailings thickener. The underflow from this 300'-diameter tailings thickener again goes to the tailings pond. The overflow is circulated in the plant and used as the wash water for the ore-concentrating system Approximately 50,000 gpm of water are circulated in the plant, with approximately 2,500 gpm of makeup water pumped from the St. Louis River. The total water requirement at the plant is estimated as follows:

44,400 gpm return from 300'-diameter tailings thickener
1,400 gpm returned as barge water from the tailings basin
2,500 gpm obtained as makeup water from the St. Louis River

48,300 gpm total water requirement

It should be noted that the use of coarse tailings (from the spiral classifier) for dike construction results in less tendency for fine, wind-blown dust in the vicinity of the tailings pond. It was suggested that any exposed fine tailings be covered by the rich organic soil readily available in the area. This process has been used in the vicinity of the concentrating plant to cover elevated areas constructed with ore tailings.

Permission was requested by ROY F. WESTON on July 9, 1971 for sampling in the plant and again on July 15, 1971 for specific wastewater analyses and review of the preliminary material balance. The information submitted by Eveleth personnel on June 25, 1971 is attached as Table C-5.

### Material Balance

The material balance was abstracted from verbal data given to ROY F. WESTON personnel on June 2 and 3, 1971 and is shown in Figure C-6. Comments received from Eveleth were included in this balance. Due to the manner in which the data were presented, the attached balance can be considered only as an approximation of the plant ore and water flows.

It is anticipated that minor changes in the water flow rates will result from the installation of a wet scrubber on the Pelletizer Furnace exhaust gas system This scrubbing operation will increase the makeup water requirements and will also increase the total water flow in the plant circulating system.

## Lind-Greenway Mine

### General

The Lind-Greenway Mine, located approximately 5 miles north of Grand Rapids, Minnesota, is one of several mining and ore-processing facilities in the Mesaba iron range owned and operated by the Jones & Laughlin Steel Corporation. This mine and concentrating process differ from the operations at Erie and Eveleth due to the type of ore being processed. The Lind-Greenway mine is a natural ore (hematite) mine, and the ore-concentrating is accomplished by a flotation process rather than by magnetic separation.

It should be noted that this plant is operated approximately 26 weeks per year. Both the mining operations and the ore-concentrating operations are terminated during the winter months. A limited number of personnel are retained in the plant at that time for general maintenance.

## Table C-5

## Sample Structures and Chemistry
## Eveleth Taconite Company

| Mesh | Class Sands | Class Overflow | 300' Thickener Underflow |
|---|---|---|---|
| + 4 | 1.5 | | |
| + 6 | 8.0 | | |
| + 8 | 18.0 | | |
| + 10 | 33.8 | | |
| + 14 | 48.7 | | |
| + 20 | 63.7 | | |
| + 28 | 73.2 | | |
| + 35 | 80.4 | | |
| + 48 | 87.4 | 0.2 | 0.2 |
| + 65 | 92.0 | 0.6 | 0.4 |
| +100 | 95.0 | 2.2 | 1.0 |
| +150 | 96.4 | 5.2 | 2.8 |
| +200 | 97.1 | 10.2 | 7.8 |
| +270 | 97.3 | 14.0 | 13.0 |
| +325 | 97.4 | 17.2 | 17.0 |
| +400 | 97.5 | 21.8 | 23.0 |
| +500 | 97.6 | 30.2 | 33.4 |
| -500 | 2.4 | 69.8 | 66.6 |
| Percent Solids | 82.5 | 7.6 | 50.9 |
| Percent Fe | 17.24 | 13.05 | 13.45 |
| Percent $SiO_2$ | 64.38 | 63.54 | 61.86 |

### Water Samples

| | pH | Turbidity JTU | Color |
|---|---|---|---|
| 300' Thickener Overflow | 8.1 | 65 | 280 |
| Barge Water | 8.3 | 0 | 0 |

# EXISTING SOLIDS AND WATER BALANCE FOR EVELETH COMPANY'S TACONITE BENEFICATION PLANT

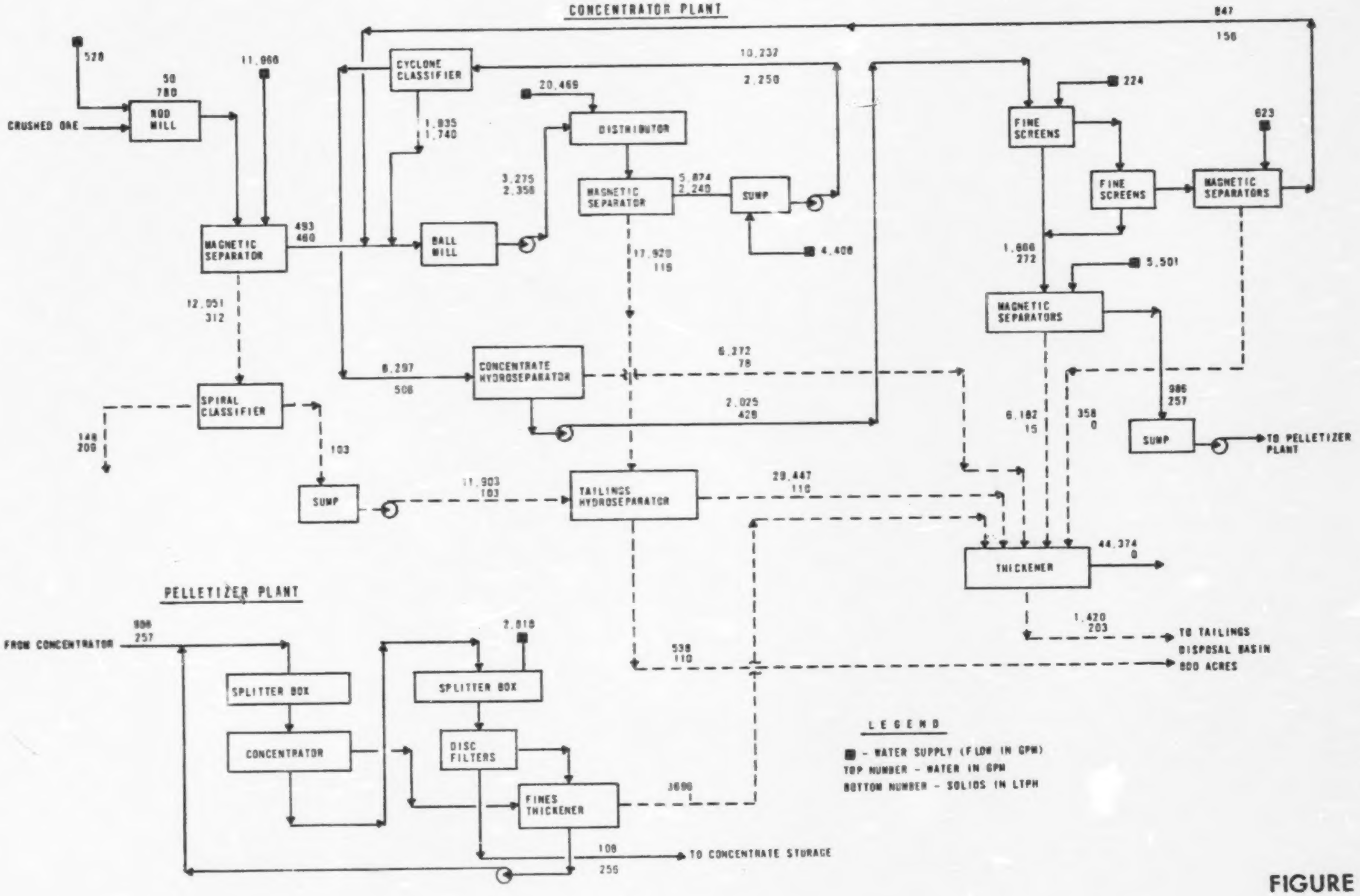

CONCENTRATOR PLANT
CRUSHED ORE
528
ROD MILL
50
780
11,966
MAGNETIC SEPARATOR
493
460
12,051
312
SPIRAL CLASSIFIER
148
200
103
SUMP
11,903
103
CYCLONE CLASSIFIER
1,835
1,740
BALL MILL
3,275
2,356
20,469
DISTRIBUTOR
MAGNETIC SEPARATOR
5,874
2,240
SUMP
4,408
10,232
2,250
17,920
116
6,297
506
CONCENTRATE HYDROSEPARATOR
6,272
78
2,025
428
TAILINGS HYDROSEPARATOR
29,447
110
538
110
847
156
224
FINE SCREENS
FINE SCREENS
623
MAGNETIC SEPARATORS
1,666
272
5,501
MAGNETIC SEPARATORS
6,182
15
358
0
986
257
SUMP
TO PELLETIZER PLANT
THICKENER
44,374
0
1,420
203
TO TAILINGS DISPOSAL BASIN 800 ACRES
PELLETIZER PLANT
FROM CONCENTRATOR
986
257
SPLITTER BOX
CONCENTRATOR
2,818
SPLITTER BOX
DISC FILTERS
FINES THICKENER
3698
1
108
256
TO CONCENTRATE STORAGE
LEGEND
■ - WATER SUPPLY (FLOW IN GPM)
TOP NUMBER - WATER IN GPM
BOTTOM NUMBER - SOLIDS IN LTPH

FIGURE C-6

### Description of Operations

The attached sheets obtained from personnel at Lind-Greenway describe the operating process, and the accompanying flow sheet (Figure C-7) gives a general picture of the flow through the concentrating facilities. This plant does not manufacture pellets. The ore is shipped from the plant in crushed form and is loaded onto ships in the Duluth harbor without being pelletized.

### Description of Plant Water Supply and Tailings System

The water supply for the Lind-Greenway Mine is obtained primarily by pumping from the mine pits. There is sufficient seepage of water into the mine pits to provide an excess of water over that required for the plant operations. Since there are no evaporating processes in the ore-concentrating facilities, makeup water is not required. All plant water is pumped to the tailings basin, and excess water is siphoned over into an adjacent lake, which flows into the Prairie River. Water is pumped from the tailings basin at a rate of approximately 12,000 gpm for use as flushing water and as spray water on the screens and classifiers used in this operation.

Separation of the iron from the silica is achieved by using a solution of ferro silicate as a flotation medium. The density of the liquid stream is adjusted to maintain the specific gravity desired for separation of the desirable ore fraction from the silica.

Samples were taken at various locations at the Mine. The analytical results of these samples are shown in Table C-6.

### Items of Interest

The items of primary interest in this plant involve the use of rake classifiers and spiral classifiers for separation of material at different sizing levels. The initial separation of the crushed ore is made on double-deck screens. All particles larger than one-quarter inch in size are discharged to the heavy-media surge pile. Undersized particles are processed by rake classifiers, with the heavy sands going to a jig surge pile. The overflow from the rake classifiers is discharged to the tailings basin.

Ore from the heavy-media surge pile is processed in heavy-media separators (spiral classifiers). Material which sinks in the high-density fluid is dewatered on screens and discharged to the load-out conveyor. The ore which floats in the heavy media is separated by a magnetic separation process to recover the ferro-silicate (densifying medium). The reject material is discharged to trucks and hauled to storage piles at the plant site. Excess water is returned to the tailings pond.

Material from the jig surge pile (less than one-quarter inch size) is concentrated on jig screens and flushed with water. The concentrated ore is processed through a dewatering classifier and the fines are discharged to rail cars for shipment. Overflow from the classifiers is recirculated in the plant as washwater or rejected to the tailings pond.

Figure C-7

LIND-GREENWAY HEAVY MEDIA PLANT

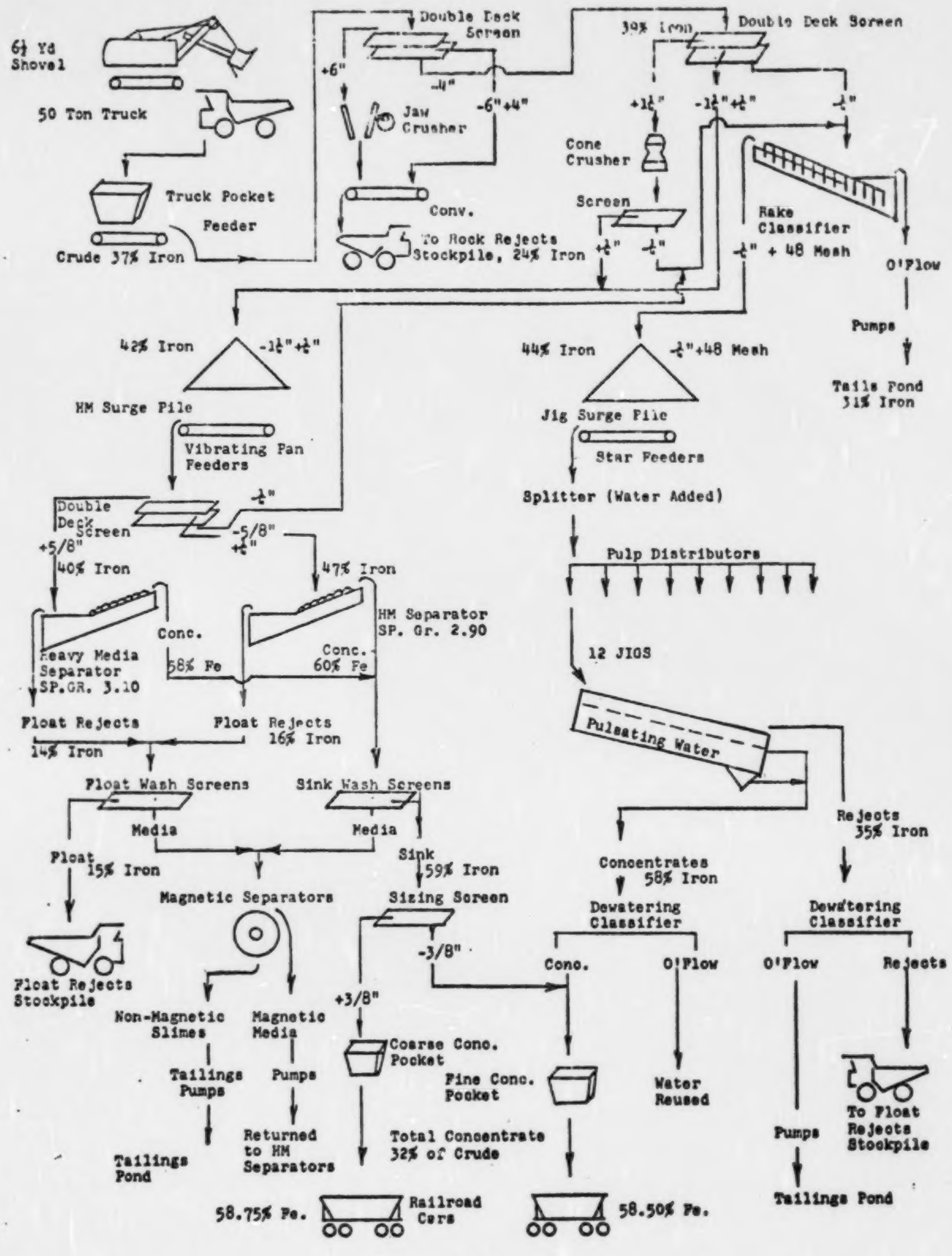

6½ Yd Shovel
50 Ton Truck
Truck Pocket
Feeder
Crude 37% Iron
Double Deck Screen
+6"
-4"
Jaw Crusher
-6"+4"
Conv.
To Rock Rejects Stockpile, 24% Iron
39% Iron
Double Deck Screen
+1½"
-1½"+½"
-½"
Cone Crusher
Screen
+½"
-½"
Rake Classifier
-½" + 48 Mesh
O'Flow
Pumps
Tails Pond 31% Iron
42% Iron
-1½"+½"
HM Surge Pile
Vibrating Pan Feeders
44% Iron
-½"+48 Mesh
Jig Surge Pile
Star Feeders
Splitter (Water Added)
Pulp Distributors
12 JIGS
Pulsating Water
Double Deck Screen
-½"
+5/8"
-5/8" +½"
40% Iron
47% Iron
Conc.
HM Separator SP. Gr. 2.90
Heavy Media Separator SP.GR. 3.10
58% Fe
Conc. 60% Fe
Float Rejects 14% Iron
Float Rejects 16% Iron
Float Wash Screens
Sink Wash Screens
Media
Media
Float 15% Iron
Sink 59% Iron
Magnetic Separators
Sizing Screen
-3/8"
+3/8"
Float Rejects Stockpile
Non-Magnetic Slimes
Magnetic Media
Tailings Pumps
Pumps
Tailings Pond
Returned to HM Separators
Coarse Conc. Pocket
Fine Conc. Pocket
Total Concentrate 32% of Crude
58.75% Fe.
Railroad Cars
58.50% Fe.
Concentrates 58% Iron
Dewatering Classifier
Conc.
O'Flow
Water Reused
Rejects 35% Iron
Dewatering Classifier
O'Flow
Rejects
Pumps
Tailings Pond
To Float Rejects Stockpile

Table C-6

Analytical Results of Samples Taken at
Lind-Greenway Mine

| Sample | pH | Alkalinity mg/l | Acidity mg/l | SS mg/l | DS mg/l | COD mg/l | Cl mg/l | $SO_4$ mg/l | F mg/l | $SiO_2$ mg/l | Fe mg/l | Mn mg/l | Ca mg/l | Mg mg/l | Cu mg/l | Zn mg/l | Cr mg/l | As mg/l | Hg µg/l | Ag mg/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rake Classifier Overflow No. 19 | 7.2 | 470 | 32 | 103,100 | 200 | | | | | | | | | | | | | | | |
| Concentrate Dewatering Classifier No. 2-13 Overflow | 7.5 | 240 | 12 | 3,520 | 138 | | | | | | | | | | | | | | | |
| Reject Dewatering Classifier Overflow No. 2-10 | 7.3 | 260 | 16 | 13,740 | 180 | | | | | | | | | | | | | | | |
| Heavy Media Classifier Overflow No. 1-41 | 7.5 | 330 | 14 | 26,300 | 130 | | | | | | | | | | | | | | | |
| Barge Water | 7.8 | 122 | 8 | 42 | 112 | 10 | 5.7 | 28.4 | 0.04 | 7.5 | <0.2 | <0.05 | 39.0 | 11.5 | <0.05 | <0.05 | <0.05 | 0.45 | 3.0 | <0.05 |

Note: Samples taken June 3, 1971.

# ATTACHMENT

## JONES & LAUGHLIN STEEL CORPORATION

### Lind-Greenway Plant

The crude ore for the plant is made up of alternate bands of iron mineralization and silica (waste). The iron minerals in the ore are hematite, goethite and limonite. The ore is considerably softer than either semi-taconite or taconite and requires little crushing. The iron bands are broken from the waste primarily by blasting and digging in the pit.

The blasted ore is loaded into and hauled by 40-50 ton capacity trucks and dumped into a crude ore pocket at the plant. The ore is moved into the plant at approximately 900 tons per hour by a steel pan conveyor.

The crude ore varies in size from chunks one foot or more across to particles which are finer than face powder. Because of the varying sizes the ore is screened on a scalping screen. All pieces of ore larger than four inches are crushed in a jaw crusher and, because of the low iron content, are rejected and hauled by truck to a rock reject stockpile.

The pieces smaller than four inches are screened again on two vibrating screens where the ore is separated into products of three different sizes: (1) a product of pieces smaller than four inches but greater than 1-1/4 inches; (2) one of pieces smaller than 1-1/4 inches but larger than 1/4 of an inch, and (3) a product of pieces smaller than 1/4 of an inch. The + 1-1/4 inch material can either be rejected as waste or if the iron content is high enough, be crushed in two cone crushers to -1-1/4 inches and used as feed for the heavy media sections. The -1-1/4 inch +1/4 inch product is transported by a series of rubber belt conveyors to a stockpile outside the plant; approximately 2,000 tons is stocked for later use. The -1/4 inch material is moved through steel troughs by water to two rake classifiers which separate the very fine -325 mesh silts or sands from the coarser material. The finest material is then pumped as waste to a tailing pond where the fine solids settle out and the water re-used in the plant. The coarser fractions are transported by conveyor belt to a stockpile outside of the plant.

The stockpile of fine material (-1/4 inch) is jig feed and is returned to the plant at the rate of 300 tons per hour. The feed is mixed with water and distributed to concentrating machines called Remer jigs which separate the iron bearing particles from the sand, clay and other silica particles contained in the feed. The iron particles, being heavier than the rest of the feed, sink to the bottom of the bed of material being treated, by the jigging or pulsating motion of the jigs. The lighter portion of the feed stays on top. Which both the heavy and light particles get to the lowest end of the jig, the light weight particles are washed to the sides of the jig and go to reject while the heavier pieces are washed over the end or gate and go to the concentrate. Two concentrate products are produced, a gate product which consists of the coarser iron particles and the hutch product made up of the finer iron particles. The two concentrate products are combined in a concentrate classifier and dewatered. The concentrate is then transported by belt conveyor to a track load-out pocket and loaded into railroad ore cars for shipment. The combined concentrate averages 58.50% iron and 10.00% silica.

The stockpile of coarse material (1-1/4 inch +1/4 inch) is called heavy media feed and is returned to the plant for treatment at the rate of 400 tons per hour. In the plant this feed is divided into two parts by screening, one part consists of pieces - 1-1/4 inch +5/8 inch in size and is called coarse heavy media feed; the other of - 5/8 inch + 1/4 inch in size is called fine heavy media feed. Both feeds are treated in identical concentrating circuits. The feed goes to a separating vessel

# ATTACHMENT

## 2

containing a slurry or mixture of ferro-silicon and water. The specific gravity of the medium should be between the specific gravities of the heavier iron particles and that of silica waste. In the vessel the iron pieces sink and the waste floats. Both the iron concentrate and the waste go to separate screens where they are thoroughly washed to recover the expensive ferro-silicon which costs from $135.00 to $175.00 per ton depending on the type used.

The heavy media concentrates are combined and transported by belt conveyor to a track load-out pocket where they are dumped into railroad ore cars for shipments. The waste is conveyed by belt and truck to a reject dump. The concentrate averages about 58.70% iron and 9.00% silica.

The jig concentrate and the heavy media concentrate are shipped in separate ore cars. These cars, when loaded, contain approximately 60 tons of concentrate each. The ore is shipped by rail to the Duluth ore docks, by ore boat to either Cleveland or Ashtabula, Ohio, and by rail to the Pittsburgh steel district.

The Lind-Greenway plant processes approximately 2,500,000 tons of plant crude per season producing about 650,000 tons of concentrate or about one ton of concentrate for each three tons of crude ore treated.

### Lind-Greenway Plant

Operating Data:

| | | |
|---|---|---|
| Gross Crude to Plant: | : | 2,500,000 long tons crude per year |
| | : | 21,000 long tons per day (3 shifts per day) |
| | : | 870 long tons per hour |
| Net Crude to Plant (plant feed) | : | 770 long tons per hour (3 shifts per day) |
| Heavy Media Section Feed (+ 1/4") | : | 400 long tons per hour (3 shifts per day) |
| Jig Feed (fines) (- 1/4") | : | 300 long tons per hour (3 shifts per day) |
| Heavy Media Concentrate (- 1-1/4 + 1/4") | : | 160 long tons per hour |
| Jig Concentrate (- 1/4") | : | 75 long tons per hour |
| Total Concentrate | : | 650,000 long tons per year |
| Stockpiled Rejects | : | 900,000 long tons per year |
| Fine Tailing (-325 mesh) | : | 700,000 long tons per year |

Water Used: approximately 12,000 gallons per minute of fine tailings pumped to tailings pond where fine solids settle out.

12,000 gallons of fresh water, pumped from tailing pond, required each minuted to process ore.

: length of tailing line approximately one mile - 5,300 feet.
: length of fresh water line approximately one mile.

: one billion gallons of water are pumped out of the pits each year.

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## ATTACHMENT

3

Equipment Data:

Preparation Section:
- 1 - 4' x 14' Hydrastroke feeder
- 1 - 54" x 113" pan conveyor
- 1 - 6' x 12' scalping screen (screen out + 4" material)
- 1 - 32" x 40" jaw crusher
- 2 - 6' x 20' doubledeck screens
- 2 - 4.25' cone crushers
- 1 - 5' x 12' doubledeck screen
- 2 - 12' x 38' rake classifiers
- 12 - rubber belt conveyors
- 2 - tailing pumps

Heavy Media Sections:
- 2 - 5' x 14' doubledeck preparation screens
- 2 - 84" Akins heavy media separators
- 4 - 6' x 6' media drain screens
- 4 - 6' x 16' media wash screens
- 4 - 30" x 72" double-drum magnetic separators
- 1 - 30" x 72" single-drum magnetic separator
- 4 - rubber belt conveyors (concentrate (2) reject and feed)
- 2 - 66" Akins heavy media densifiers

Jig Section:
- 1 - 4' x 8' tramp screen
- 2 - 6' pulp distributors
- 6 - 5' x 16' Remer primary jigs
- 6 - 5' x 16' Remer secondary jigs
- 2 - 72" Akins concentrate and reject dewatering classifier
- 3 - belt conveyor (concentrate (2) and feed)

Miscellaneous Information

This plant contains:

| | |
|---|---|
| 160 | motors |
| 25 | pumps |
| 9,294 | feet of conveyor belt |

# APPENDIX D

## DETAILED DESCRIPTION OF DISPOSAL ALTERNATIVES

Alternative No. 1 D-1
Alternative No. 2 D-11
Alternative No. 3 D-20
Alternative No. 4 D-29
Alternative No. 5 D-37

# APPENDIX D

## DETAILED DESCRIPTION OF DISPOSAL ALTERNATIVES

### Introduction

This Appendix provides a detailed description of the processing, handling, and disposal operations of each of the five alternatives presented in Section V of the main report. The description of each alternative includes a detailed discussion accompanied by a summary list of the major units and sizes, and a breakdown of estimated capital and annual costs. The cost breakdowns provide the basis for a detailed cost comparison of the five proposed alternatives. Included in these cost tabulations are the major treatment units or handling operations and their respective capital costs.

### Alternative No. 1

#### Principal Operations

1. On-site processing of concentrator plant wastewater for removal of suspended solids.
2. Removal of coarse tailings (>150-mesh) from the wastewater by hydroseparators, followed by dewatering on screens.
3. Flocculation of fine tailings with organic polymers, and subsequent removal from the wastewater by gravity thickening.
4. Dewatering of the thickened solids using vacuum filters.
5. Conveyance of the dewatered coarse and fine tailings to railroad loading facilities.
6. Rail haul of coarse and fine tailings to the Lower Lax Lake land disposal area.
7. Treatment of recycled process water prior to discharge to Lake Superior.

#### Description of Major Facilities

A generalized plot plan showing the location of the major facilities for all alternatives is presented as Figure D-1. A preliminary flow diagram of the facilities proposed in Alternative No. 1 is shown on Figure D-2.

##### On-Site Processing

Concentrator wastewater would be diverted into realigned launders, which would carry the total plant flow to three 140'-diameter Hydroseparators. The West Launder would be intercepted upstream of the point where a flow of 120,000 gpm of fresh water is now added to flush the tailings to the delta. The elimination of this flushing water would reduce the hydraulic requirements of the treatment facility and also reduce the total pumping requirements of the Silver Bay Plant. The existing launders would be retained as emergency bypasses, but the West Launder would be relocated to make room for the treatment facility.

Hydroseparators would provide a separation at approximately 150 mesh. The underflow solids (>150-mesh) would be withdrawn by center-column pumping using three 4,500 gpm rubber-lined solids pumps and transported to screens prior to dewatering. Three standby pumps would be provided to insure continuous operation. Overflow from the Hydroseparators would flow to two of the three processing lines. One standby line is provided to maintain a continuous treatment operation in case of equipment failure.

Organic polymers would be added to the Hydroseparator overflow ahead of the rapid-mix tanks at a dosage rate of 2 mg/l. A 30,000-gallon rubber-lined tank housed in the control building would be used for bulk polymer storage. The polymer concentrate would be fed to a mix tank to prepare a 5 percent polymer solution. This solution would be transferred to the polymer feed tanks, from which it would be fed to the rapid-mix tanks.

The rapid-mix tanks would provide a detention time of 1 minute, with two units in operation to assure complete dispersion of the polymer. Wastewater would then flow to the flocculation basins to aid in the formation of the floc. Five rectangular flocculators in parallel, with a detention time of 10 minutes each, are provided for each process line to absorb the energy of the wastewater and prevent short-circuiting.

The flocculated wastewater would then flow to the center well of the 305'-diameter thickeners. The transport launders from the flocculation basins to the thickeners would provide an average flow velocity of 3 fps, to prevent the settling of solids in the launder and to keep the floc from breaking up.

Flocculated fines would settle to the bottom of the thickeners and be collected at the center well for center-column pumping. This underflow would be removed at a concentration of 40 to 50 percent solids by one of two 5,000-gpm sludge pumps. A standby pump is provided to assure continuous operation.

Clarified effluent from the thickeners would be returned via two 60" concrete pipes to the plant's water intake located in the northwest corner of the harbor. The pipe walls would be coated to protect the pipe against velocities in excess of 15 fps.

### Water Treatment Plant

Gradual buildup in concentration of suspended and dissolved solids can result from the continuous recycle of process water. This is especially true during winter operation, when calcium chloride (used to prevent the ore from freezing in the railroad cars) finds its way into the process water. An excessive buildup of calcium in the process would interfere with the pelletizing process and would adversely affect final product quality. For this reason, a water treatment plant has been proposed to control the water quality. The water treatment plant would withdraw and treat a portion of the thickener overflow and an equal amount of "clean" harbor water would replace that portion withdrawn from this system for treatment. With this method of withdrawal and dilution, the solids buildup in the recycled process water can be controlled. The thickener overflow that is treated will require the removal of suspended solids prior to discharge into the lake. Little if any removal of dissolved solids can be expected in this treatment system.

Research performed by the Reserve Mining Company (and reported in a memo from R.S. Lemire to K.M. Haley dated January 28, 1971) indicated that a withdrawal rate equal to seven percent of the total volume of process water could be expected to provide recycled process water of acceptable quality. For purposes of design, a flow equal to 8.5 percent of the design flow of 290,000 gpm was used to size the water treatment facilities. It should be noted, however, that this percentage figure should be verified through pilot plant testing before a final design is established.

Chemical flocculation would be used to treat the 25,000 gpm flow to be withdrawn from the thickener overflow. The flow would be split in half, and flow by gravity to two rapid-mix tanks. Addition for inorganic chemical and mixing would be performed prior to flocculation. Two rectangular flocculation basins are provided for each line to aid in the formation of flocculated solids. Approximately eight minutes of flocculation would be provided before the flow is discharged to the 140'-diameter clarifiers. The clarifiers would have a design overflow rate of 1,000 gpd/sq.ft. and provide a detention time of more than two hours. Overflow from these clarifiers would be discharged to Lake Superior through a sub-surface diffuser system. Underflow solids would be pumped through the center column of the clarifier and would be mixed and disposed of with the fine tailings.

### Tailings Transport

Underflow solids from the thickeners and sludge from the water treatment plant would be pumped to disc-type vacuum filters for dewatering. The discs would be 9 feet in diameter, and 15 separate discs would be included in each unit. In all, eleven filter units are provided, including two standbys. The filter cake would be expected to contain approximately 30 percent moisture, and a filter yield of 150 lbs./sq.ft./hr. would be expected.

Coarse tailings, which are removed from the wastewater as Hydroseparator underflow would be pumped to screens for dewatering. A 150-mesh screen is provided so that fines (-150 mesh) captured with the coarse solids can be removed. The water and fines removed from the coarse tailings would be returned to the treatment process.

Dewatered coarse and fine tailings would be conveyed on a 42" conveyor to the railroad loading facilities for loading into bottom-dump ore cars that would be used only for hauling tailings. Bottom-dump cars would be used because of their more rapid unloading and the resulting shorter turn-around time. A comparison between bottom dump cars and solid-bottom gondola cars (reported by the Bechtel Corporation in their Proposals 6 through 9) indicated that less total capital investment would be required with the bottom dump carriers.

Two trains of 68 cars each would be required to haul all the tailings to the Lax Lake area for disposal. The bottom-dump cars would be equipped with heaters and insultation to assure continuous operation during freezing weather. A thawing shed is also provided for emergencies.

At the unloading point, tailings would be conveyed to the disposal area for dam construction and/or disposal. If required, coarse tailings could be hauled separately to the disposal site for dam construction. This would require additional handling facilities for coarse and fine tailings, however, and has not been considered in this alternative.

### On-Land Disposal

The on-land disposal of tailings is proposed for the low-land marshy area south of Lax Lake. This area (referred to as the Lower Lax Lake area) has ample capacity to store the estimated volume of tailings.

In previous studies, an emergency spillway was provided to release excess water captured in the basin. Additional freebroad was provided in some cases to contain wet-weather runoff in order to prevent overtopping the dam However, upstream diversion of the streams draining into the basin may be more economical and more reliable, and this latter approach is incorporated in the proposed site.

Six separate earthen-type dams, with a final elevation of 1,300 feet, are proposed for the basin. Figure 11 in Section V of the main report shows the proposed location for these embankments. Dam E is designed not only to contain the tailings but also to isolate the Lax Lake area, which appears to have some recreational and resort value to the surrounding region. The location of Dam E, however, will back up water into Fortythree Creek and eventually flood the Lax Lake area. To eliminate this, four 20-foot tunnels at location H have been proposed to provide a discharge for this water. These tunnels would handle the discharge from the East Branch of the Beaver River and Fortythree Creek. An additional diversion structure located at point G would direct Big Thirtynine Creek to the Beaver River. The only remaining stream flowing into the impoundment area would be Little Thirtynine Creek, which could be contained in the much smaller storage provided on the top of the tailings.

The dust problem that could result from wind action on the in-place tailings has been the cause of much concern. Planting and revegetation would be the final solution to dusting problems. For an interim measure, however, an inert encrustating agent could be applied to the dusting surface of the tailings to stabilize them The agent would be sprayed in dilute solutions upon the tailings to form a stable crust with a few inches of tailings. As long as the surface remains undisturbed, the crust would remain intact, thus minimizing the dust problem.

### Major Units

A summary list of the major units and equipment items, with the principal dimensional and capacity information, is presented in the following pages.

## SUMMARY OF MAJOR UNITS AND SIZES
## ALTERNATIVE NO. 1

| | |
|---|---|
| **On-Site Processing** | |
| **Launder Realignment** | |
| **East Launder** | |
| Length | 450' |
| Width | 20' |
| Height | 5' |
| Construction Material | Concrete w/steel plate |
| **West Launder** | |
| Length | 550' |
| Width | 20' |
| Height | 5' |
| Construction Material | Concrete w/steel plate |
| **Hydroseparators** | |
| Number | 3 |
| Diameter | 140' |
| Depth | 20' |
| **Underflow pumps** | |
| Number | 6 (including 2 standbys) |
| Capacity | 4,500 gpm. each |
| Type | Centrifugal. Variable-speed |
| **Rapid-Mix Tanks** | |
| Number | 3 (including 1 standby) |
| Volume | 150,000 gallons |
| Shape | Square |
| Dimensions | 24' x 49' x 15' SWD + 2' freeboard (fb.) |
| Detention Time | 60 seconds |
| Mixers | 6 (2 per tank) |
| **Flocculator** | |
| Sets | 3 (including 1 standby) |
| Tanks | 5 per set |
| **Tank Dimensions** | |
| Length | 140' |
| Width | 20' |
| SWD | 20' + 2' fb |
| Detention Time | 10 minutes |
| **Mixers** | |
| Number | 5 per tank (25 per set) |
| Type | Variable-speed |
| Maximum Speed | 50 rpm |
| **Wastewater Launders (to Clarifiers)** | |
| Number | 3 |
| Length | 300' (maximum) |
| Width | 15' |
| Height | 10' |
| Construction Material | Concrete w/steel plate |
| **Thickeners** | |
| Number | 3 |
| Type | Circular |
| Diameter | 305' |
| Depth | 20' SWD + 2' fb |
| Overflow rate | 3,000 gpd/sq.ft. |
| Construction Material | Concrete |
| **Underflow Pumps** | |
| Number | 6 (including 3 standbys) |
| Capacity | 5,000 gpm. each |
| Type | Centrifugal. Variable-speed |
| Operation | Center-Column Removal |
| **Polymer Addition Facilities** | |
| **Bulk Storage Tank w/Nitrogen Seal** | |
| Volume | 30,000 gallons |
| Material | Steel |
| **Bulk Polymer Transfer Pump** | |
| Number | 2 |
| Capacity | 50 gpm |
| Type | Gear |
| **Polymer Mix Tank** | |
| Number | 1 |
| Volume | 5,000 gallons |
| Type | Steel w/liner |
| Mixer Size | 3 HP |
| **Bulk Polymer Pumps to Mix Tank** | |
| Number | 2 |
| Capacity | 15 gpm |
| Type | Gear |
| **Polymer Feed Pumps to Feed Tank** | |
| Number | 2 |
| Capacity | 15 gpm |
| Type | Centrifugal |
| **Polymer Feed Tanks** | |
| Number | 2 |
| Volume | 5,000 gallons |
| Type | Steel w/liner and insulated |
| Mixer Size (1 per tank) | 2 HP |
| **Polymer Feed Pumps** | |
| Number | 4 |
| Capacity (variable) | 10 to 15 gpm |
| **Effluent Recycle Pipeline** | |
| Length | 1,000' |
| Number | 2 |
| Diameter | 60" |
| Type | Concrete |
| Additional Requirements | Protective liner for velocities in excess of 15 fps. |
| **Coarse Solids Dewatering** | |
| Type | Double Screen |
| Number | 12 |
| Fine Screen Size | 150 mesh |
| **Fine Solids Dewatering** | |
| Type | Disc-vacuum filters |
| Number | 11 (including 2 standby) |
| Disc Diameter | 9' |
| Discs per filter | 15 |
| Filter Yield | 150 lbs./sq.ft./hr. |
| Cake Moisture | 30 percent |
| **Water Treatment Plant** | |
| **Rapid-Mix Tanks** | |
| Number | 2 |
| Volume | 12,500 gallons |
| Dimensions | 13' x 13' x 10' SWD + 2' fb |
| Detention Time | 60 seconds |
| Type | Concrete |
| Mixers | 2 (1 per tank) |
| **Flocculators** | |
| Sets | 2 |
| Tanks per set | 2 |
| **Tank Dimensions** | |
| Length | 40' |
| Width | 15' |
| SWD | 15' + 2' fb |
| Detention Time | 10 minutes |
| **Mixers** | |
| Number | 8 (2 per tank) |
| Type | Variable-speed |
| Maximum Speed | 50 rpm |
| **Clarifiers** | |
| Number | 2 |
| Type | Circular |
| Diameter | 140' |
| Depth | 15' SWD + 2' fb |

| | |
|---|---|
| Overflow Rate | 1,000 gpd/sq.ft. |
| Construction Material | Concrete |
| Underflow Pumps | |
| Number | 4 (2 are standbys) |
| Capacity | 10 gpm |
| Type | Centrifugal, Variable-speed |
| Operation | Center-Column Removal |
| Tailings Transport | |
| Combined Tailings Transfer Conveyor A-1 | |
| Width | 42" |
| Length | 1,700' |
| Lift | 113' |
| Load | 4,000 STPH |
| Construction | Enclosed and insulated |
| Combined Tailings Transfer Conveyor A-2 | |
| Width | 42" |
| Length | 1,400' |
| Lift | 200' |
| Load | 4,000 STPH |
| Construction | Enclosed and insulated |
| Combined Tailings Shuttle Conveyor | |
| Width | 42" |
| Length | 90' |
| Lift | Top of Loading Bins |
| Load | 4,000 STPH |
| Construction | Enclosed and insulated |
| Rail Haul Requirements | |
| Locomotives | |
| Number | 9 |
| Type | 6-axle, diesel-electric |
| HP | 2,000 (each) |
| Tailings Cars | |
| Number | 150 |
| Capacity | 88 Tons (each) |
| Special Equipment | Heated and insulated |
| Caboose | |
| Number | 4 |
| Length | 30' |
| Loadout and Surge Bins | |
| Number | 12 |
| Capacity | 1,400 Tons (each) |
| Special Equipment | Heated and insulated |
| Thaw Shed | |
| Number | 1 |
| Power Required | 1,200 KW |
| Take-away Conveyor | |
| Number | 1 |
| Dimensions | 60" x 50' (no lift) |
| Transfer Conveyor | |
| Number | 1 |
| Dimensions | 60" x 600' x 80' lift |
| Disposal Site Requirements | |
| Railroad Transfer Conveyor | |
| Number | 1 |
| Dimensions | 54" x 8,000' x 300' lift |
| Trunk Conveyor | |
| Number | 1 |
| Dimensions | 54" x 8,000' |
| Stacking Conveyor | |
| Number | 1 |
| Dimensions | 54" x 4,000' (shiftable) |
| Stacker w/Tripper | |
| Number | 1 |
| Dimensions | 120'-boom, crawler-mounted |
| Emergency Stacker | |
| Number | 1 |
| Dimensions | 54" x 160' x 46' lift |

## Cost Estimates

Capital and Annual Cost estimates for the facilities and processes proposed for Alternative No. 1 are presented in Table D-1. The contingency provided in the total capital cost estimate includes professional services for design, plus an allowance for the escalation in prices that may occur by the time construction is started. The estimates of annual costs include both fixed costs (interest and depreciation over a 20-year period) and operating costs. Labor and Supervision costs have been based on the manning of four shifts (to cover 24-hour, 7-day operation), and on average rates of $5.00/hour for labor and $1,100/month for supervision. Electrical power cost estimates are based on operating horsepower requirements only, with a unit power cost of $0.012 per KW-HR.

## Table D-1

### Alternative No. 1
### All Tailings Rail Hauled to Lower Lax Lake

### CAPITAL COST ESTIMATE

| | | |
|---|---|---|
| **On-Site Processing** | | |
| Launder Realignment | $ 590,000 | |
| Hydroseparators | 1,780,000 | |
| Rapid Mix Tank | 192,000 | |
| Flocculators | 1,795,000 | |
| Thickeners | 4,392,000 | |
| Polymer Addition | 208,000 | |
| Wastewater Transport Launders | 2,600,000 | |
| Treated Effluent Recycle | 318,000 | |
| Solids Dewatering - Coarse - Screens | 188,000 | |
| Fines - Disc Filters | 882,000 | |
| Site Work | 170,000 | |
| Piling | 1,236,000 | |
| Control Building | 932,000 | |
| Piping, Electrical, and Instrumentation | 5,349,000 | |
| Sub-Total | | $20,632,000 |
| **Water Treatment** | | |
| Rapid Mix Tanks | $ 26,000 | |
| Flocculation Tanks | 141,000 | |
| Chemical Addition Facilities | 15,000 | |
| Clarifiers | 933,000 | |
| Site Work | 8,000 | |
| Piping, Electrical, and Instrumentation | 394,000 | |
| Sub-Total | | 1,517,000 |
| **Tailings Transport** | | |
| Tailings Conveyors | $ 1,261,000 | |
| Railroad Loading and Unloading | 880,000 | |
| Additional Rolling Stock | 8,700,000 | |
| Disposal Area Conveyors | 12,750,000 | |
| Electrical Distribution | 2,400,000 | |
| Sub-Total | | 25,991,000 |
| **Disposal Site** | | |
| Starter Dam | $ 6,700,000 | |
| Diversion Dams and Channels | 10,317,000 | |
| Sub-Total | | 17,017,000 |
| Contingency at 15 percent | | 9,774,000 |
| **TOTAL CAPITAL COST** | | $74,931,000 |

### ANNUAL COST ESTIMATE

| | | |
|---|---|---|
| **Operating Costs** | | |
| Labor and Supervision | $ 1,520,000 | |
| Maintenance and Repair | 2,117,000 | |
| Utilities (Power + Fuel) | 910,000 | |
| Chemicals | 920,000 | |
| Dam Construction and Maintenance | 1,783,000 | |
| Sub-Total | | $ 7,250,000 |
| **Fixed Costs** | | |
| Interest | $ 3,746,000 | |
| Depreciation | 3,371,000 | |
| Sub-Total | | 7,117,000 |
| **TOTAL ANNUAL COST** | | $14,367,000 |

## RESERVE MINING COMPANY
SILVER BAY, MINNESOTA
PLOT PLAN
PROPOSED WASTEWATER TREATMENT FACILITIES

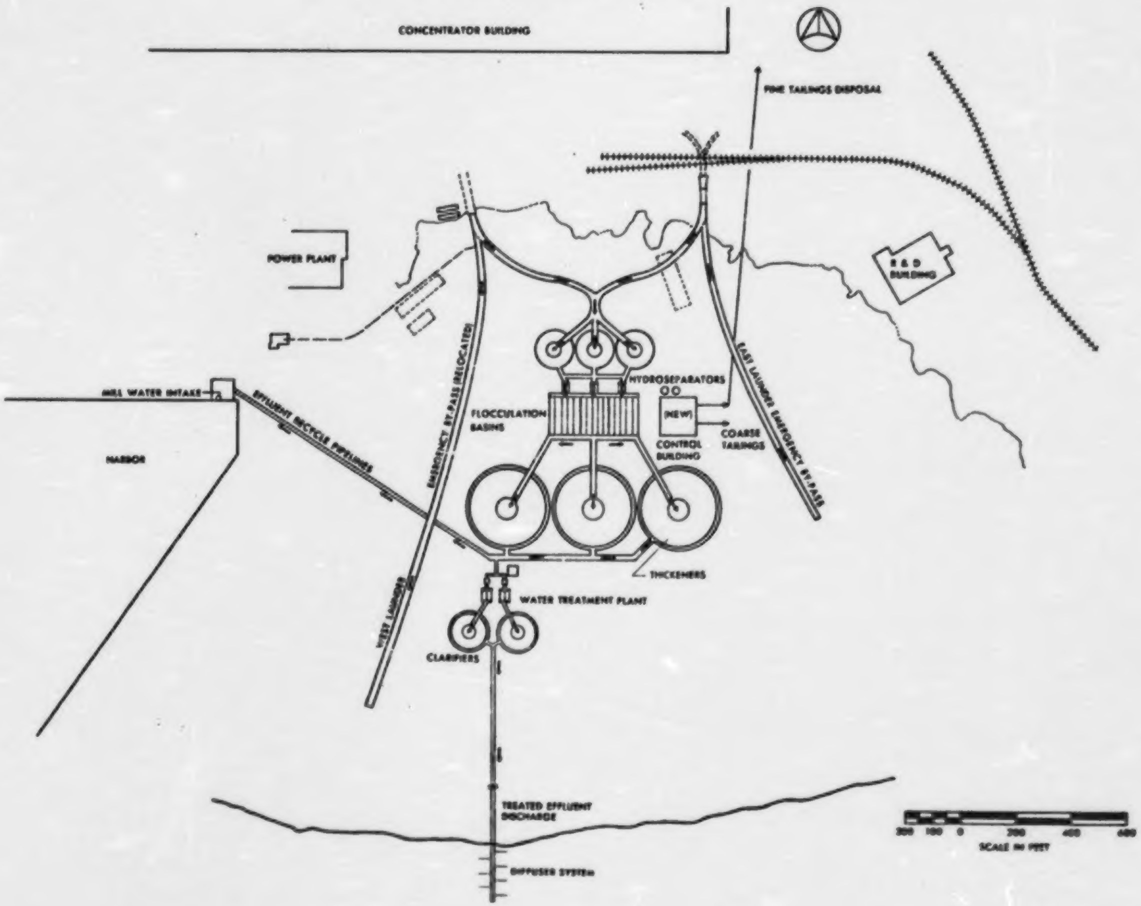
CONCENTRATOR BUILDING
FINE TAILINGS DISPOSAL
POWER PLANT
R & D BUILDING
HYDROSEPARATORS
FLOCCULATION BASINS
(NEW)
CONTROL BUILDING
COARSE TAILINGS
EMERGENCY BY-PASS (RELOCATED)
EAST LAUNDER EMERGENCY BY-PASS
MILL WATER INTAKE
EFFLUENT RECYCLE PIPELINES
HARBOR
THICKENERS
WATER TREATMENT PLANT
CLARIFIERS
WEST LAUNDER
TREATED EFFLUENT DISCHARGE
DIFFUSER SYSTEM
200 100 0 200 400 600
SCALE IN FEET

FIGURE D-1

## RESERVE MINING COMPANY

SILVER BAY, MINNESOTA
PROCESS FLOW DIAGRAM
PROPOSED WASTEWATER TREATMENT FACILITIES
ALTERNATIVE 1

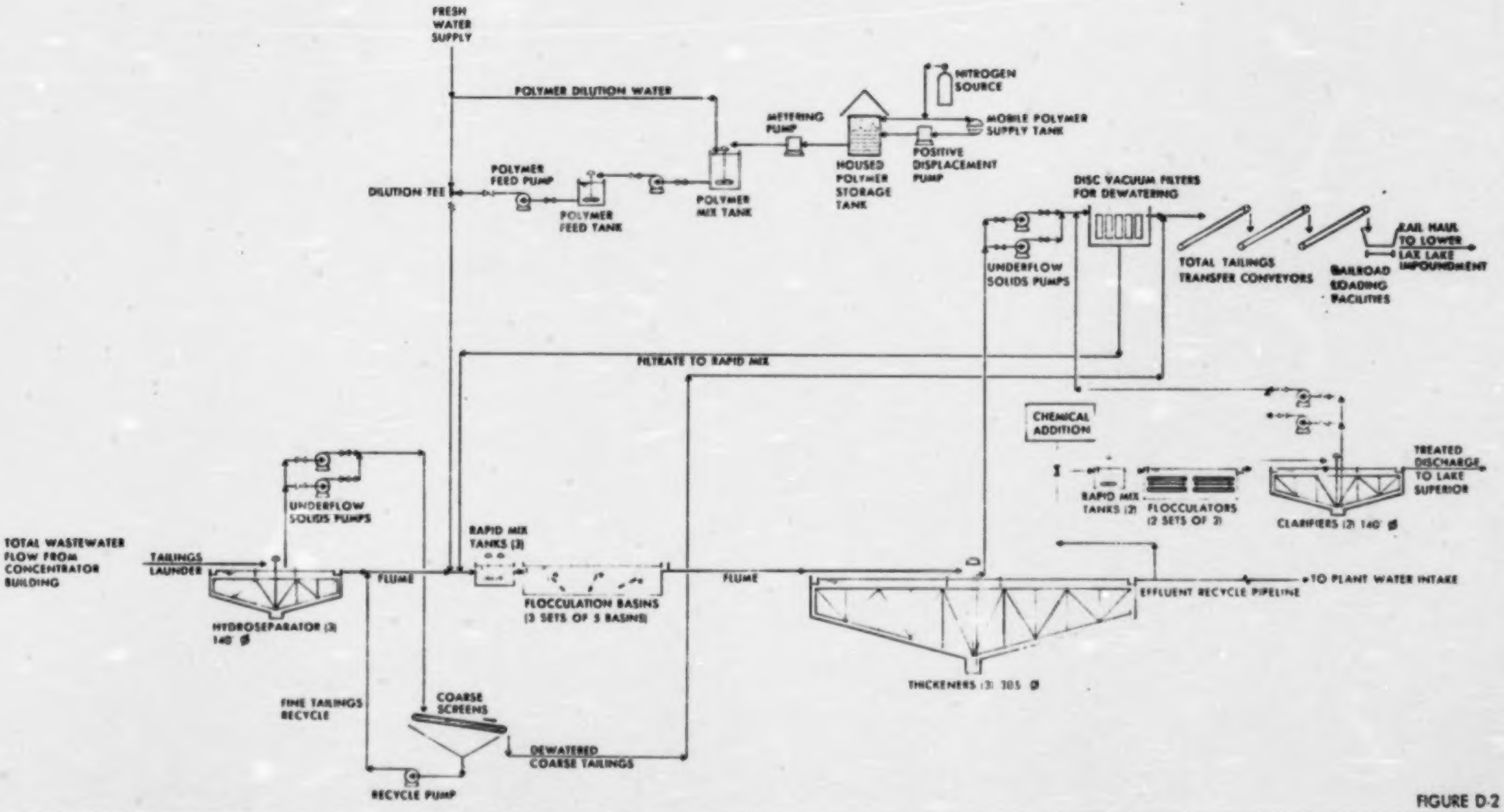
FRESH WATER SUPPLY
POLYMER DILUTION WATER
NITROGEN SOURCE
METERING PUMP
MOBILE POLYMER SUPPLY TANK
POSITIVE DISPLACEMENT PUMP
HOUSED POLYMER STORAGE TANK
POLYMER FEED PUMP
DILUTION TEE
POLYMER FEED TANK
POLYMER MIX TANK
DISC VACUUM FILTERS FOR DEWATERING
UNDERFLOW SOLIDS PUMPS
TOTAL TAILINGS TRANSFER CONVEYORS
RAILROAD LOADING FACILITIES
RAIL HAUL TO LOWER LAX LAKE IMPOUNDMENT
FILTRATE TO RAPID MIX
CHEMICAL ADDITION
RAPID MIX TANKS (2)
FLOCCULATORS (2 SETS OF 2)
CLARIFIERS (2) 140' Ø
TREATED DISCHARGE TO LAKE SUPERIOR
UNDERFLOW SOLIDS PUMPS
TOTAL WASTEWATER FLOW FROM CONCENTRATOR BUILDING
TAILINGS LAUNDER
HYDROSEPARATOR (3) 140' Ø
FLUME
RAPID MIX TANKS (3)
FLOCCULATION BASINS (3 SETS OF 5 BASINS)
FLUME
EFFLUENT RECYCLE PIPELINE
TO PLANT WATER INTAKE
THICKENERS (3) 305' Ø
FINE TAILINGS RECYCLE
COARSE SCREENS
DEWATERED COARSE TAILINGS
RECYCLE PUMP

FIGURE D-2

## Alternative No. 2

This alternative involves the on-site processing of the concentrator plant wastewater for the removal of suspended solids. Coarse tailings would be removed from the wastewater by Hydroseparators and conveyed to the railroad loading facilities for rail haul to the Lax Lake disposal area. The fine tailings would be flocculated with organic polymers and subsequently removed from the wastewater by gravity thickeners. Thickened solids would be pumped by overland pipeline to the Lower Lax Lake area for on-land disposal.

### Description of Major Facilities

A preliminary flow diagram of the facilities proposed in Alternative No. 2 is shown on Figure D-3.

#### On-Site Processing

Concentrator wastewater would be diverted into realigned launders, which would carry the total plant flow to three 140'-diameter Hydroseparators. The West Launder would be intercepted upstream of the point where a flow of 120,000 gpm of fresh water is now added to flush the tailings to the delta. The elimination of this flushing water would reduce the hydraulic requirements of the treatment facility and also reduce the total pumping requirements of the Silver Bay Plant. The existing launders would be retained as emergency bypasses, but the West Launder would be relocated to make room for the treatment facility.

Hydroseparators would provide a separation at approximately 150 mesh. The underflow solids (>150-mesh) would be withdrawn by center-column pumping using three 4,500 gpm rubber-lined solids pumps and transported to screens prior to dewatering. Three standby pumps would be provided to insure continuous operation. Overflow from the Hydroseparators would flow to two of the three processing lines. One standby line is provided to maintain a continuous treatment operation in case of equipment failure.

Organic polymers would be added to the Hydroseparator overflow ahead of the rapid-mix tanks at a dosage rate of 2 mg/L. A 30,000-gallon rubber-lined tank housed in the control building would be used for bulk polymer storage. The polymer concentrate would be fed to a mix tank to prepare a 5 percent polymer solution. This solution would be transferred to the polymer feed tanks, from which it would be fed to the rapid-mix tanks.

The rapid-mix tanks would provide a detention time of 1 minute, with two units in operation to assure complete dispersion of the polymer. Wastewater would then flow to the flocculation basins to aid in the formation of the floc. Five rectangular flocculators in parallel, with a detention time of 10 minutes each, are provided for each process line to absorb the energy of the wastewater and prevent short-circuiting.

The flocculated wastewater would then flow to the center well of the 305'-diameter thickeners. The transport launders from the flocculation basins to the thickeners would provide an average flow velocity of 3 fps, to prevent the settling of solids in the launder, and to keep the floc from breaking up.

Flocculated fines would settle to the bottom of the thickeners and be collected at the center well for center-column pumping. This underflow would be removed at a concentration of 40 to 50 percent solids by one of two 5,000-gpm sludge pumps. A standby pump is provided to assure continuous operation.

Clarified effluent from the thickeners would be returned via two 60" concrete pipes to the plant's water intake located in the northwest corner of the harbor. The pipe walls would be coated to protect the pipe against velocities in excess of 15 fps.

### Water Treatment Plant

Gradual buildup in concentration of suspended and dissolved solids can result from the continuous recycle of process water. This is especially true during winter operation, when calcium chloride (used to prevent the ore from freezing in the railroad cars) finds its way into the process water. An excessive buildup of calcium in the process would interfere with the pelletizing process and would adversely affect final product quality. For this reason, a water treatment plant has been proposed to control the water quality. The water treatment plant would withdraw and treat a portion of the thickener overflow and an equal amount of "clean" harbor water would replace that portion withdrawn from this system for treatment. With this method of withdrawal and dilution, the solids buildup in the recycled process water can be controlled. The thickener overflow that is treated will require the removal of suspended solids prior to discharge into the lake. Little if any removal of dissolved solids can be expected in this treatment system.

Research performed by the Reserve Mining Company (and reported in a memo from R.S. Lemire to K.M. Haley dated January 28, 1971) indicated that a withdrawal rate equal to seven percent of the total volume of process water could be expected to provide recycled process water of acceptable quality. For purposes of design, a flow equal to 8.5 percent of the design flow of 290,000 gpm was used to size the water treatment facilities. It should be noted, however, that this percentage figure should be verified through pilot plant testing before a final design is established.

Chemical flocculation would be used to treat the 25,000 gpm flow to be withdrawn from the thickener overflow. The flow would be split in half, and flow by gravity to two rapid-mix tanks. Addition for inorganic chemical and mixing would be performed prior to flocculation. Two rectangular flocculation basins are provided for each line to aid in the formation of flocculated solids. Approximately eight minutes of flocculation would be provided before the flow is discharged to the 140'-diameter clarifiers. The clarifiers would have a design overflow rate of 1,000 gpd/sq.ft. and provide a detention time of more than two hours. Overflow from these clarifiers would be discharged to Lake Superior through a sub-surface diffuser system. Underflow solids would be pumped through the center column of the clarifier and would be mixed and disposed of with the fine tailings.

### Tailings Transport

Underflow solids from the thickeners and sludge from the water treatment plant would be pumped to the slurry mix tank prior to pumping to the disposal area. The mix tank would have an approximate volume of 500,000 gallons and a mixer would be provided to maintain the slurry solids in suspension.

The overland pipeline which would transport the fine tailings to the Lower Lax Lake impoundment basin, would be fed by four 2,300 gpm positive displacement pumps. A standby pump would be available to provide continuity in the operation. These pumps would be capable of overcoming the 1,300 ft. total head differential which would exist between the delta pumping station and the impoundment area. Therefore, no intermediate pumping stations would be required.

Coarse tailings, which would be removed as Hydroseparator underflow, would be pumped to screens for dewatering. A 150-mesh screen would permit the fines (-150 mesh) trapped with the coarse tailings to be removed. The water and fines removed from the coarse tailings would be returned to the treatment process.

Tailings transport conveyors would transport the dewatered coarse tailings to the railroad loading facilities, and a shuttle conveyor would lift the tailings into the six loading bins located west of the existing rotary ore-car dumper. The transport conveyors would be enclosed and insulated for cold weather protection.

The loading bins would load bottom-dump ore cars that would be used only for hauling tailings. Bottom-dump cars would be used because of their rapid unloading and the resulting shorter turn-a-round times. A comparison between bottom dump cars and solid-bottom gondola cars indicated that less total capital investment would be required if bottom dump carriers were used. The cars would be heated and insulated to assure continuous operation during freezing weather. A thawing shed would be provided for emergencies.

At the unloading point tailings would be conveyed to the dam sites for dam construction. The coarse tailings would form the major portion of the dike. Rock fill would be used to stabilize the dam and an impervious layer of compacted native earth would be placed on the basin side of the dam.

### On-Land Disposal

The on-land disposal of tailings is proposed for the low-land marshy area south of Lax Lake. This area (referred to as the Lower Lax Lake area) has ample capacity to store the estimated volume of tailings.

In previous studies, an emergency spillway was provided to release excess water captured in the basin. Additional freebroad was provided in some cases to contain wet-weather runoff in order to prevent overtopping the dam However, upstream diversion of the streams draining into the basin may be more economical and more reliable, and this latter approach is incorporated in the proposed site.

Six separate earthen-type dams, with a final elevation of 1,300 feet, are proposed for the basin. Figure 11 in Section V of the main report shows the proposed location for these embankments. Dam E is designed not only to contain the tailings but also to isolate the Lax Lake area, which appears to have some recreational and resort value to the surrounding region. The location of Dam E, however, will back up water into Fortythree Creek and eventually flood the Lax Lake area. To eliminate this, four 20-foot tunnels at location H have been proposed to provide a discharge for this water. These tunnels would handle the discharge from the East Branch of the Beaver River and Fortythree Creek. An additional diversion structure located at point G would direct Big Thirtynine Creek to the Beaver River. The only remaining stream flowing into the impoundment area would be Little Thirtynine Creek, which could be contained in the much smaller storage provided on the top of the tailings.

The dust problem that could result from wind action on the in-place tailings has been the cause of much concern. Planting and revegetation would be the final solution to dusting problems. For an interim measure, however, an inert encrustating agent could be applied to the dusting surface of the tailings to stabilize them The agent would be sprayed in dilute solutions upon the tailings to form a stable crust with a few inches of tailings. As long as the surface remains undisturbed, the crust would remain intact, thus minimizing the dust problem.

### Major Units

A summary list of the major units and equipment items, with the principal dimensional and capacity information, is presented in the following pages.

## SUMMARY OF MAJOR UNITS AND SIZES
## ALTERNATIVE NO. 2

| | |
|---|---|
| **On-Site Processing** | |
| **Launder Realignment** | |
| **East Launder** | |
| Length | 450' |
| Width | 20' |
| Height | 5' |
| Construction Material | Concrete w/steel plate |
| **West Launder** | |
| Length | 550' |
| Width | 20' |
| Height | 5' |
| Construction Material | Concrete w/steel plate |
| **Hydroseparators** | |
| Number | 3 |
| Diameter | 140' |
| Depth | 20' |
| **Underflow Pumps** | |
| Number | 6 (including 2 standbys) |
| Capacity | 4,500 gpm, each |
| Type | Centrifugal, Variable-speed |
| **Rapid-Mix Tanks** | |
| Number | 3 (including 1 standby) |
| Volume | 150,000 gallons |
| Shape | Square |
| Dimensions | 24' x 49' x 15' SWD +2' freeboard (fb.) |
| Detention Time | 60 seconds |
| Mixers | 6 (2 per tank) |
| **Flocculator** | |
| Sets | 3 (including 1 standby) |
| Tanks | 5 per set |
| Tank Dimensions | |
| Length | 140' |
| Width | 20' |
| SWD | 20' + 2' fb |
| Detention Time | 10 minutes |
| Mixers | |
| Number | 5 per tank (25 per set) |
| Type | Variable-speed |
| Maximum Speed | 50 rpm |
| **Wastewater Launders (to Clarifiers)** | |
| Number | 3 |
| Length | 300' (maximum) |
| Width | 15' |
| Height | 10' |
| Construction Material | Concrete w/steel plate |
| **Thickeners** | |
| Number | 3 |
| Type | Circular |
| Diameter | 305' |
| Depth | 20' SWD + 2' fb |
| Overflow rate | 3,000 gpd/sq.ft. |
| Construction Material | Concrete |
| **Underflow Pumps** | |
| Number | 6 (including 3 standbys) |
| Capacity | 5,000 gpm, each |
| Type | Centrifugal, Variable-speed |
| Operation | Center-Column Removal |
| **Polymer Addition Facilities** | |
| **Bulk Storage Tank w/Nitrogen Seal** | |
| Volume | 30,000 gallons |
| Material | Steel |
| **Bulk Polymer Transfer Pump** | |
| Number | 2 |
| Capacity | 50 gpm |
| Type | Gear |
| **Polymer Mix Tank** | |
| Number | 1 |
| Volume | 5,000 gallons |
| Type | Steel w liner |
| Mixer Size | 3 HP |
| **Bulk Polymer Pumps to Mix Tank** | |
| Number | 2 |
| Capacity | 15 gpm |
| Type | Gear |
| **Polymer Feed Pumps to Feed Tank** | |
| Number | 2 |
| Capacity | 15 gpm |
| Type | Centrifugal |
| **Polymer Feed Tanks** | |
| Number | 2 |
| Volume | 5,000 gallons |
| Type | Steel w liner and insulated |
| Mixer size (1 per tank) | 2 HP |
| **Polymer Feed Pumps** | |
| Number | 4 |
| Capacity (variable) | 10 to 15 gpm |
| **Effluent Recycle Pipeline** | |
| Length | 1,000' |
| Number | 2 |
| Diameter | 60" |
| Type | Concrete |
| Additional Requirements | Protective liner for velocities in excess of 15 fps. |
| **Coarse Solids Dewatering** | |
| Type | Double Screen |
| Number | 12 |
| Fine Screen Size | 150 mesh |
| **Fine Solids Dewatering** | |
| Type | Disc-vacuum filters |
| Number | 11 (including 2 standby) |
| Disc Diameter | 9' |
| Discs per filter | 15 |
| Filter Yield | 150 lbs./sq.ft./hr. |
| Cake Moisture | 30 percent |
| **Water Treatment Plant** | |
| **Rapid-Mix Tanks** | |
| Number | 2 |
| Volume | 12,500 gallons |
| Dimensions | 13' x 13' x 10' SWD + 2' fb. |
| Detention Time | 60 seconds |
| Type | Concrete |
| Mixers | 2 (1 per tank) |
| **Flocculators** | |
| Sets | 2 |
| Tanks per set | 2 |
| Tank Dimensions | |
| Length | 40' |
| Width | 15' |
| SWD | 15' + 2' fb. |
| Detention Time | 10 minutes |
| Mixers | |
| Number | 8 (2 per tank) |
| Type | Variable-Speed |
| Maximum Speed | 50 gpm |
| **Clarifiers** | |
| Numbers | 2 |
| Type | Circular |
| Diameter | 140' |
| Depth | 15' SWD + 2' fb |
| Overflow Rate | 1,000 gpd/sq.ft. |
| Construction Material | Concrete |
| **Underflow Pumps** | |
| Number | 4 (2 are standbys) |
| Capacity | 10 gpm |

| | |
|---|---|
| Type | Centrifugal, Variable-speed |
| Operation | Center-Column Removal |
| Tailings Transport | |
| Fine Tailings Slurry Tank | |
| Number | 1 |
| Volume (approximate) | 500,000 gallons |
| Length | 58' |
| Width | 58' |
| Depth | 20' + 2' fb. |
| Material of Construction | Concrete |
| Mixer | 1 |
| Size | 250 HP |
| Fine Tailings Slurry Pump | |
| Number | 5 ( including 1 standby) |
| Type | Positive-Displacement |
| Capacity | 2,300 gpm |
| Fine Tailings Pipeline | |
| Number | 2 |
| Length (each) | 21,150' |
| Diameter | 14" |
| Minimum Velocity | 8 fps. |
| Coarse Tailings Dewatering | |
| Type | Double Screen |
| Number | 12 |
| Fine-Screen Size | 150 mesh |
| Coarse Tailings Transfer Conveyor A-1 | |
| Width | 42" |
| Length | 1,700' |
| Lift | 113' |
| Load | 2,000 STPH |
| Const. | Enclosed and Insulated |
| Coarse Tailings Transfer Conveyor A-2 | |
| Width | 42" |
| Length | 1,400' |
| Lift | 200' |
| Load | 2,000 STPH |
| Construction | Enclosed and Insulated |
| Fine Tailings Shuttle Conveyor | |
| Width | 42" |
| Length | 90' |
| Load | 2,000 STPH |
| Lift | To top of loading bins |
| Construction | Enclosed and Insulated |
| Rail-Haul Requirements | |
| Locomotives | |
| Number | 5 |
| Type | 6-axle, diesel-electric |
| HP | 2,000 (each) |
| Tailings Cars | |
| Number | 75 |
| Size | 88 Tons |
| Special Equipment | Heated and Insulated |
| Caboose | |
| Number | 2 |
| Type | Close "NE" 8 wheel |
| Length | 30' |
| Generator Car | |
| Number | 1 |
| Power Capacity | 250 KW |
| Loadout and Surge Bins | |
| Number | 12 |
| Size | 1,400 tons (each) |
| Special Equipment | Heated and Insulated |
| Thaw Shed | |
| Number | 1 |
| Power Required | 1,200 KW |
| Take-away Conveyor | |
| Number | 1 |
| Dimensions | 60" x 50' (no lift) |
| Transfer Conveyor | |
| Number | 1 |
| Dimensions | 60" x 600' x 80' lift |
| Disposal Area Requirements | |
| Railroad Transfer Conveyor | |
| Number | 1 |
| Dimensions | 42" x 8,000' x 300' lift |
| Shuttle Conveyor | |
| Number | 2 |
| Dimensions | 42" x 100' |
| Site Transfer Conveyors | |
| Number | 7 |
| Dimensions | 42" x 1,000' |
| Stacking Conveyor | |
| Number | 2 |
| Dimensions | 42" x 2,000' (shiftable) |
| Stacker w/Tripper | |
| Number | 2 |
| Dimensions | 120'-boom crawler-mounted |
| Emergency Stacker | |
| Number | 1 |
| Dimensions | 42" x 160' x 46' lift |

### Cost Estimates

Capital and Annual Cost estimates for the facilities and processes proposed for Alternative No. 2 are presented in Table D-2. The contingency provided in the total capital cost estimate includes professional services for design, plus an allowance for the escalation in prices that may occur by the time construction is started. The estimates of annual costs include both fixed costs (interest and depreciation over a 20-year period) and operating costs. Labor and Supervision costs have been based on the manning of four shifts (to cover 24-hour, 7-day operation), and on average rates of $5.00/hour for labor and $1,100/month for supervision. Electrical power cost estimates are based on operating horsepower requirements only, with a unit power cost of $0.012 per KW-HR.

## Table D-2

### Alternative No. 2
### Coarse Tailings Rail Hauled to Lower Lax Lake
### Fine Tailings Pumped to Lax Lake

### CAPITAL COST ESTIMATE

| | | |
|---|---|---|
| **On-Site Processing** | | |
| Launder Realignment | $ 590,000 | |
| Hydroseparators | 1,780,000 | |
| Rapid Mix Tanks | 192,000 | |
| Flocculators | 1,795,000 | |
| Thickeners | 4,392,000 | |
| Polymer Addition | 208,000 | |
| Wastewater Transport Launders | 2,600,000 | |
| Solids Dewatering - Coarse | 188,000 | |
| Treated Effluent Recycle | 318,000 | |
| Site Work | 170,000 | |
| Piling | 1,236,000 | |
| Control Building | 932,000 | |
| Piping, Electrical, and Instrumentation | 5,040,000 | |
| Sub-Total | | $19,441,000 |
| **Water Treatment** | | |
| Rapid Mix Tanks | $ 26,000 | |
| Flocculation Tanks | 141,000 | |
| Chemical Addition Facilities | 15,000 | |
| Clarifiers | 933,000 | |
| Site Work | 8,000 | |
| Piping, Electrical, and Instrumentation | 394,000 | |
| Sub-Total | | 1,517,000 |
| **Tailings Transport** | | |
| Coarse Tailings Conveyors | $ 1,216,000 | |
| Railroad Loading and Unloading | 880,000 | |
| Additional Rolling Stock | 6,200,000 | |
| Disposal Area Conveyors | 12,750,000 | |
| Electrical Distribution | 2,400,000 | |
| Fine Tailings Pump House | 190,000 | |
| Fine Tailings Transport Pumps | 1,956,000 | |
| Fine Tailings Pipeline | 1,017,000 | |
| Sub-Total | | 26,609,000 |
| **Disposal Site** | | |
| Starter Dam | $ 6,700,000 | |
| Diversion Dams and Channels | 10,317,000 | |
| Sub-Total | | 17,017,000 |
| Contingency at 15 percent | | 9,688,000 |
| **TOTAL CAPITAL COST** | | $74,272,000 |

### ANNUAL COST ESTIMATE

| | | |
|---|---|---|
| **Operating Costs** | | |
| Labor and Supervision | $ 1,500,000 | |
| Maintenance and Repair | 1,928,000 | |
| Utilities (Power and Fuel) | 1,168,000 | |
| Chemicals | 920,000 | |
| Dam Construction and Maintenance | 1,783,000 | |
| Sub-Total | | $ 7,299,000 |
| **Fixed Costs** | | |
| Interest | $ 3,713,000 | |
| Depreciation | 3,342,000 | |
| Sub-Total | | 7,055,000 |
| **TOTAL ANNUAL COST** | | $14,354,000 |

RESERVE MINING COMPANY
SILVER BAY, MINNESOTA
PROCESS FLOW DIAGRAM
PROPOSED WASTEWATER TREATMENT FACILITIES
ALTERNATIVE 2

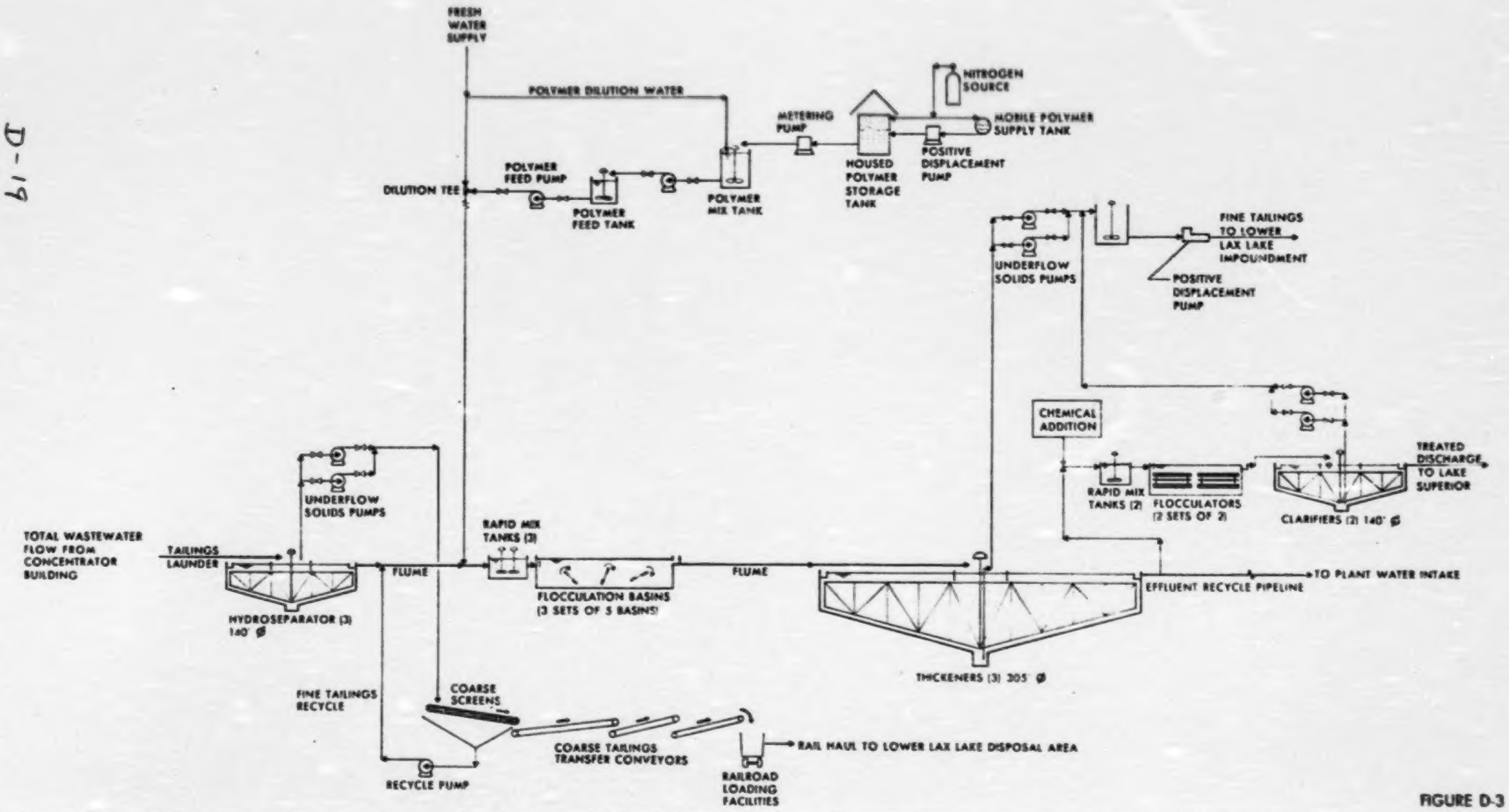
FRESH WATER SUPPLY
POLYMER DILUTION WATER
NITROGEN SOURCE
METERING PUMP
MOBILE POLYMER SUPPLY TANK
POSITIVE DISPLACEMENT PUMP
HOUSED POLYMER STORAGE TANK
DILUTION TEE
POLYMER FEED PUMP
POLYMER FEED TANK
POLYMER MIX TANK
FINE TAILINGS TO LOWER LAX LAKE IMPOUNDMENT
UNDERFLOW SOLIDS PUMPS
POSITIVE DISPLACEMENT PUMP
CHEMICAL ADDITION
TREATED DISCHARGE TO LAKE SUPERIOR
UNDERFLOW SOLIDS PUMPS
RAPID MIX TANKS (2)
FLOCCULATORS (2 SETS OF 2)
CLARIFIERS (2) 140' Ø
TOTAL WASTEWATER FLOW FROM CONCENTRATOR BUILDING
TAILINGS LAUNDER
RAPID MIX TANKS (3)
FLUME
FLUME
FLOCCULATION BASINS (3 SETS OF 5 BASINS)
EFFLUENT RECYCLE PIPELINE
TO PLANT WATER INTAKE
HYDROSEPARATOR (3) 140' Ø
THICKENERS (3) 305' Ø
FINE TAILINGS RECYCLE
COARSE SCREENS
RAIL HAUL TO LOWER LAX LAKE DISPOSAL AREA
COARSE TAILINGS TRANSFER CONVEYORS
RECYCLE PUMP
RAILROAD LOADING FACILITIES

FIGURE D-3

Alternative No. 3

This alternative involves the on-site processing of the concentrator plant wastewater for the removal of suspended solids. Coarse tailings would be removed from the wastewater by Hydroseparators, dewatered, and conveyed to the delta edge for disposal in Lake Superior. Fine tailings would be flocculated with organic polymers and subsequently removed from the wastewater by gravity settling. Underflow solids dewatered by disc-type vacuum filters and conveyed to the railroad loading facilities for railhaul to the Lower Lax Lake disposal area.

Description of Major Facilities

A preliminary flow diagram of the facilities proposed in Alternative No. 3 is shown on Figure D-4.

On-Site Processing

Concentrator wastewater would be diverted into realigned launders, which would carry the total plant flow to three 140'-diameter Hydroseparators. The West Launder would be intercepted upstream of the point where a flow of 120,000 gpm of fresh water is now added to flush the tailings to the delta. The elimination of this flushing water would reduce the hydraulic requirements of the treatment facility and also reduce the total pumping requirements of the Silver Bay Plant. The existing launders would be retained as emergency bypasses, but the West Launder would be relocated to make room for the treatment facility.

Hydroseparators would provide a separation at approximately 150 mesh. The underflow solids (>150-mesh) would be withdrawn by center-column pumping using three 4,500 gpm rubber-lined solids pumps and transported to screens prior to dewatering. Three standby pumps would be provided to insure continuous operation. Overflow from the Hydroseparators would flow to two of the three processing lines. One standby line is provided to maintain a continuous treatment operation in case of equipment failure.

Organic polymers would be added to the Hydroseparator overflow ahead of the rapid-mix tanks at a dosage rate of 2 mg/l. A 30,000-gallon rubber-lined tank housed in the control building would be used for bulk polymer storage. The polymer concentrate would be fed to a mix tank to prepare a 5 percent polymer solution. This solution would be transferred to the polymer feed tanks, from which it would be fed to the rapid-mix tanks.

The rapid-mix tanks would provide a detention time of 1 minute, with two units in operation to assure complete dispersion of the polymer. Wastewater would then flow to the flocculation basins to aid in the formation of the floc. Five rectangular flocculators in parallel, with a detention time of 10 minutes each, are provided for each process line to absorb the energy of the wastewater and prevent short-circuiting.

The flocculated wastewater would then flow to the center well of the 305'-diameter thickeners. The transport launders from the flocculation basins to the thickeners would provide an average flow velocity of 3 fps, to prevent the settling of solids in the launder, and to keep the floc from breaking up.

Flocculated fines would settle to the bottom of the thickeners and be collected at the center well for center-column pumping. This underflow would be removed at a concentration of 40 to 50 percent solids by one of two 5,000-gpm sludge pumps. A standby pump is provided to assure continuous operation.

Clarified effluent from the thickeners would be returned via two 60" concrete pipes to the plant's water intake located in the northwest corner of the harbor. The pipe walls would be coated to protect the pipe against velocities in excess of 15 fps.

### Water Treatment Plant

Gradual buildup in concentration of suspended and dissolved solids can result from the continuous recycle of process water. This is especially true during winter operation, when calcium chloride (used to prevent the ore from freezing in the railroad cars) finds its way into the process water. An excessive buildup of calcium in the process would interfere with the pelletizing process and would adversely affect final product quality. For this reason, a water treatment plant has been proposed to control the water quality. The water treatment plant would withdraw and treat a portion of the thickener overflow and an equal amount of "clean" harbor water would replace that portion withdrawn from this system for treatment. With this method of withdrawal and dilution, the solids buildup in the recycled process water can be controlled. The thickener overflow that is treated will require the removal of suspended solids prior to discharge into the lake. Little if any removal of dissolved solids can be expected in this treatment system.

Research performed by the Reserve Mining Company (and reported in a memo from R.S. Lemire to K.M. Haley dated January 28, 1971) indicated that a withdrawal rate equal to seven percent of the total volume of process water could be expected to provide recycled process water of acceptable quality. For purposes of design, a flow equal to 8.5 percent of the design flow of 290,000 gpm was used to size the water treatment facilities It should be noted, however, that this percentage figure should be verified through pilot plant testing before a final design is established.

Chemical flocculation would be used to treat the 25,000 gpm flow to be withdrawn from the thickener overflow. The flow would be split in half, and flow by gravity to two rapid-mix tanks. Addition for inorganic chemical and mixing would be performed prior to flocculation. Two rectangular flocculation basins are provided for each line to aid in the formation of flocculated solids. Approximately eight minutes of flocculation would be provided before the flow is discharged to the 140'-diameter clarifiers. The clarifiers would have a design overflow rate of 1,000 gpd/sq.ft. and provide a detention time of more than two hours. Overflow from these clarifiers would be discharged to Lake Superior through a sub-surface diffuser system Underflow solids would be pumped through the center column of the clarifier and would be mixed and disposed of with the fine tailings.

### Tailings Transport

Underflow solids from the thickeners and sludge from the water treatment plant would be pumped to disc type vacuum filters for dewatering. Dewatered fine tailings with a cake moisture content of 30 percent would be conveyed to the railroad loading facilities located west of the existing rotary car dumping facilities. Filtrate from the vacuum filters would be returned to the treatment plant.

Fine tailings conveyors with a total length of 3,100' would be required to lift the tailings over 300' to the railroad loading facilities. A shuttle conveyor (enclosed and insulated for cold weather operation) would lift the tailings into the loading bins.

The railroad loading bins with a capacity of 1,400 tons would be capable of loading 60 cars an hour. Hopper bottom-dump cars would be used because of their rapid unloading and the resulting shorter turnaround time. A comparison between bottom dump cars and the solid bottom gondola cars indicated that less total capital investment would be required if bottom dump carriers were used. The cars would be heated and insulated to assure continuous operation, and a thawing shed would be provided for emergencies.

At the unloading point tailings are conveyed to the impoundment area for disposal. Because tailings are brought to the area in a dewatered form the placement of the tailings can be controlled to a greater degree than in the pipeline alternatives. Dusting, however, will be a problem with this alternative and must be controlled.

### On-Land Disposal

The on-land disposal of tailings is proposed for the low land marshy area south of Lax Lake. This area (referred to as the Lower Lax Lake area) has ample capacity to store the estimated volume of tailings.

In previous studies, an emergency spillway was provided to release excess water captured in the basin. Additional freebroad was provided in some cases to contain wet-weather runoff in order to prevent overtopping the dam. However, upstream diversion of the streams draining into the basin may be more economical and more reliable, and this latter approach is incorporated in the proposed site.

Six separate earthen-type dams, with a final elevation of 1,300 feet, are proposed for the basin. Figure 11 in Section V of the main report shows the proposed location for these embankments. Dam E is designed not only to contain the tailings but also to isolate the Lax Lake area, which appears to have some recreational and resort value to the surrounding region. The location of Dam E, however, will back up water into Fortythree Creek and eventually flood the Lax Lake area. To eliminate this, four 20-foot tunnels at location H have been proposed to provide a discharge for this water. These tunnels would handle the discharge from the East Branch of the Beaver River and Fortythree Creek. An additional diversion structure located at point G would direct Big Thirtynine Creek to the Beaver River. The only remaining stream flowing into the impoundment area would be Little Thirtynine Creek, which could be contained in the much smaller storage provided on the top of the tailings.

The dust problem that could result from wind action on the in-place tailings has been the cause of much concern. Planting and revegetation would be the final solution to dusting problems. For an interim measure, however, an inert encrustating agent could be applied to the dusting surface of the tailings to stabilize them. The agent would be sprayed in dilute solutions upon the tailings to form a stable crust with a few inches of tailings. As long as the surface remains undisturbed, the crust would remain intact, thus minimizing the dust problem.

The impoundment dam would still be necessary to contain surface runoff from the tailings and the fines which it would carry. Controlled discharge of this water could be practiced when an acceptable discharge quality could be achieved. The impoundment dam would be constructed of coarse tailings.

The coarse tailings, which are removed from the wastewater as hydroseparator underflow will be pumped to screens for dewatering. A 150 mesh separation is provided so that fines (-150 mesh) trapped with the coarse solids can be removed before disposal. The water and fines that are removed from the coarse tailings are returned to the treatment process. The resulting dewatered tailings would be discharged to conveyors which would carry the tailings to the delta discharge point or the railroad loading point for use in dam construction.

### Major Units

A summary list of the major units and equipment items, with the principal dimensional and capacity information, is presented in the following pages.

## SUMMARY OF MAJOR UNITS AND SIZES
## ALTERNATIVE NO. 3

| | |
|---|---|
| **On-Site Processing** | |
| **Launder Realignment** | |
| **East Launder** | |
| Length | 450' |
| Width | 20' |
| Height | 5' |
| Construction Material | Concrete w/ steel plate |
| **West Launder** | |
| Length | 550' |
| Width | 20' |
| Height | 5' |
| Construction Material | Concrete w/ steel plate |
| **Hydroseparators** | |
| Number | 3 |
| Diameter | 140' |
| Depth | 20' |
| **Underflow pumps** | |
| Number | 6 (including 2 standbys) |
| Capacity | 4,500 gpm, each |
| Type | Centrifugal, Variable-speed |
| **Rapid-Mix Tanks** | |
| Number | 3 (including 1 standby) |
| Volume | 150,000 gallons |
| Shape | Square |
| Dimensions | 24' x 49' x 15' SWD<br>+ 2' freeboard (fb) |
| Detention Time | 60 seconds |
| Mixers | 6 (2 per tank) |
| **Flocculator** | |
| Sets | 3 (including 1 standby) |
| Tanks | 5 per set |
| Tank Dimensions | |
| Length | 140' |
| Width | 20' |
| SWD | 20' + 2' fb |
| Detention Time | 10 minutes |
| Mixers | |
| Number | 5 per tank (25 per set) |
| Type | Variable-speed |
| Maximum Speed | 50 rpm |
| **Wastewater Launders (to Clarifiers)** | |
| Number | 3 |
| Length | 300' (maximum) |
| Width | 15' |
| Height | 10' |
| Construction Material | Concrete w/ steel plate |
| **Thickeners** | |
| Number | 3 |
| Type | Circular |
| Diameter | 305' |
| Depth | 20' SWD + 2' fb |
| Overflow rate | 3,000 gpd/sq.ft. |
| Construction Material | Concrete |
| **Underflow Pumps** | |
| Number | 6 (including 3 standbys) |
| Capacity | 5,000 gpm, each |
| Type | Centrifugal, Variable-speed |
| Operation | Center-Column Removal |
| **Polymer Addition Facilities** | |
| **Bulk Storage Tank w/ Nitrogen Seal** | |
| Volume | 30,000 gallons |
| Material | Steel |
| **Bulk Polymer Transfer Pump** | |
| Number | 2 |
| Capacity | 50 gpm |
| Type | Gear |
| **Polymer Mix Tank** | |
| Number | 1 |
| Volume | 5,000 gallons |
| Type | Steel w/liner |
| Mixer Size | 3 HP |
| **Bulk Polymer Pumps to Mix Tank** | |
| Number | 2 |
| Capacity | 15 gpm |
| Type | Gear |
| **Polymer Feed Pumps to Feed Tank** | |
| Number | 2 |
| Capacity | 15 gpm |
| Type | Centrifugal |
| **Polymer Feed Tanks** | |
| Number | 2 |
| Volume | 5,000 gallons |
| Type | Steel w/liner and insulated |
| Mixer size (1 per tank) | 2 HP |
| **Polymer Feed Pumps** | |
| Number | 4 |
| Capacity (variable) | 10 to 15 gpm |
| **Effluent Recycle Pipeline** | |
| Length | 1,000' |
| Number | 2 |
| Diameter | 60" |
| Type | Concrete |
| Additional Requirements | Protective liner for velocities in excess of 15 fps. |
| **Coarse Solids Dewatering** | |
| Type | Double Screen |
| Number | 12 |
| Fine Screen Size | 150 mesh |
| **Fine Solids Dewatering** | |
| Type | Disc-vacuum filters |
| Number | 11 (including 2 standby) |
| Disc Diameter | 9' |
| Discs per filter | 15 |
| Filter Yield | 150 lbs./sq.ft. hr. |
| Cake Moisture | 30 percent |
| **Water Treatment Plant** | |
| **Rapid-Mix Tanks** | |
| Number | 2 |
| Volume | 12,500 gallons |
| Dimensions | 13' x 13' x 10' SWD + 2' fb |
| Detention Time | 60 seconds |
| Type | Concrete |
| Mixers | 2 (1 per tank) |
| **Flocculators** | |
| Sets | 2 |
| Tanks per set | 2 |
| Tank Dimensions | |
| Length | 40' |
| Width | 15' |
| SWD | 15' + 2' fb |
| Detention Time | 10 minutes |
| Mixers | |
| Number | 8 (2 per tank) |
| Type | Variable-Speed |
| Maximum Speed | 50 rpm |
| **Clarifiers** | |
| Number | 2 |
| Type | Circular |

| | |
|---|---|
| Diameter | 140' |
| Depth | 15' SWD + 2' fb |
| Overflow Rate | 1,000 gpd/sq.ft. |
| Construction Material | Concrete |
| Underflow Pumps | |
| Number | 4 (2 are standbys) |
| Capacity | 10 gpm |
| Type | Centrifugal, Variable-speed |
| Operation | Center-Column Removal |
| Tailings Transport | |
| Coarse Solids Dewatering | |
| Type | Double screen |
| Number | 12 |
| Fine-Screen Size | 150 mesh |
| Coarse Tailings Conveyor to Delta | |
| Width | 42" |
| Length | 2,500' |
| Drop | 45' |
| Total Load | 2,000 STPH |
| Coarse Tailings Stacking Conveyor | |
| Width | 42" |
| Lift | 30' |
| Horizontal Reach | 400' |
| Type | Swivel Base |
| Fine Tailings Dewatering | |
| Type | Disc-Type Vacuum Filters |
| Number | 11 (including 2 standbys) |
| Disc Diam. | 9' |
| Discs per filter | 15 |
| Filter Yield | 150 lbs./sq.ft./hr. |
| Cake Moisture | 30% |
| Fine Tailings Transfer Conveyor A-1 | |
| Width | 42" |
| Length | 1,700' |
| Lift | 113' |
| Load | 2,000 TPH |
| Construction | Enclosed and Insulated |
| Fine Tailings Transfer Conveyor A-2 | |
| Width | 42" |
| Length | 1,400' |
| Lift | 200' |
| Load | 2,000 TPH |
| Construction | Enclosed and Insulated |
| Fine Tailings Shuttle Conveyor | |
| Width | 42" |
| Length | 90' |
| Load | 2,000 STPH |
| Lift | To top of RR Loading Bins |
| Construction | Enclosed and Insulated |
| Railhaul Requirements | |
| Locomotives | |
| Number | 5 |
| Type | 6-axle, diesel electric |
| HP | 2,000 (each) |
| Tailings Cars | |
| Number | 66 |
| Type | Bottom Dump |
| Size | 88 Tons (each) |
| Special Equipment | Heated and Insulated |
| Caboose | |
| Number | 2 |
| Length | 30' |
| Generator Car | |
| Number | 1 |
| Power Capacity | 250 KW |
| Load Out and Surge Bins | |
| Number | 12 |
| Size | 1,400 tons (each) |
| Special Equipment | Heated and Insulated |
| Thaw Shed | |
| Number | 1 |
| Power Required | 1,200 KW |
| Takeaway Conveyor | |
| Number | 1 |
| Dimensions | 60" x 50' (no lift) |
| Transfer Conveyor | |
| Number | 1 |
| Dimensions | 60" x 600' x 80' lift |
| Disposal Site Requirements | |
| Railroad Transfer Conveyor | |
| Number | 1 |
| Dimensions | 42" x 8,000' x 300' lift |
| Shuttle Conveyors | |
| Number | 2 |
| Dimensions | 42" x 1,000' |
| Site Transfer Conveyors | |
| Number | 7 |
| Dimensions | 42" x 1,000' |
| Stacking Conveyors | |
| Number | 2 |
| Dimensions | 42" x 2,000' (shiftable) |
| Stacker with Tripper | |
| Number | 1 |
| Dimensions | 120'-boom, crawler-monuted |
| Emergency Stacker | |
| Number | 1 |
| Dimensions | 42" x 160' x 46' lift |

## Cost Estimates

Capital and Annual Cost estimates for the facilities and processes proposed for Alternative No. 3 are presented in Table D-3. .The contingency provided in the total capital cost estimate includes professional services for design, plus an allowance for the escalation in prices that may occur by the time construction is started. The estimates of annual costs include both fixed costs (interest and depreciation over a 20-year period) and operating costs. Labor and Supervision costs have been based on the manning of four shifts (to cover 24-hour, 7-day operation), and on average rates of $5.00/hour for labor and $1,100/month for supervision. Electrical power cost estimates are based on operating horsepower requirements only, with a unit power cost of $0.012 per KW-HR.

## Table D-3

### Alternative No. 3
Coarse Tailing (+150 mesh) to Delta
Fines Rail Hauled to Lower Lax Lake

### CAPITAL COST ESTIMATE

| | | |
|---|---|---|
| **On-Site Processing** | | |
| Launder Realignment | $ 590,000 | |
| Hydroseparators | 1,780,000 | |
| Rapid Mix Tank | 192,000 | |
| Flocculators | 1,795,000 | |
| Thickeners | 4,392,000 | |
| Polymer Addition | 208,000 | |
| Wastewater Transport Launders | 2,600,000 | |
| Treated Effluent Recycle | 318,000 | |
| Solids Dewatering - Coarse - Screen | 188,000 | |
| Fines - Disc Filters | 882,000 | |
| Site Work | 170,000 | |
| Piling | 1,236,000 | |
| Control Building | 932,000 | |
| Piping, Electrical, and Instrumentation | 5,349,000 | |
| Sub-Total | | $20,632,000 |
| **Water Treatment** | | |
| Rapid Mix Tanks | $ 26,000 | |
| Flocculation Tanks | 141,000 | |
| Chemical Addition Facilities | 15,000 | |
| Clarifiers | 933,000 | |
| Site Work | 8,000 | |
| Piping, Electrical, and Instrumentation | 394,000 | |
| Sub-Total | | 1,517,000 |
| **Tailings Transport** | | |
| Coarse Tailings Conveyors | $ 790,000 | |
| Fine Tailings Conveyors | 1,261,000 | |
| Railroad Loading and Unloading | 880,000 | |
| Railroad Rolling Stock | 4,400,000 | |
| Disposal Area Conveyor | 12,750,000 | |
| Electrical Distribution | 2,400,000 | |
| Sub-Total | | 22,481,000 |
| **Disposal Site** | | |
| Starter Dam | $ 6,700,000 | |
| Diversion Dams and Channels | 10,317,000 | |
| Sub-Total | | 17,017,000 |
| Contingency at 15 percent | | 9,247,000 |
| **TOTAL CAPITAL COST** | | $70,894,000 |

### ANNUAL COST ESTIMATE

| | | |
|---|---|---|
| **Operating Costs** | | |
| Labor and Supervision | $ 1,591,000 | |
| Maintenance and Repair | 1,891,000 | |
| Utilities (Power and Fuel) | 683,000 | |
| Chemical Cost | 920,000 | |
| Dam Construction and Maintenance | 1,783,000 | |
| Sub-Total | | $ 6,868,000 |
| **Fixed Costs** | | |
| Interest | $ 3,545,000 | |
| Depreciation | 3,191,000 | |
| Sub-Total | | 6,736,000 |
| **TOTAL ANNUAL COST** | | $13,604,000 |

## RESERVE MINING COMPANY
SILVER BAY, MINNESOTA
PROCESS FLOW DIAGRAM
PROPOSED WASTEWATER TREATMENT FACILITIES
ALTERNATIVE 3

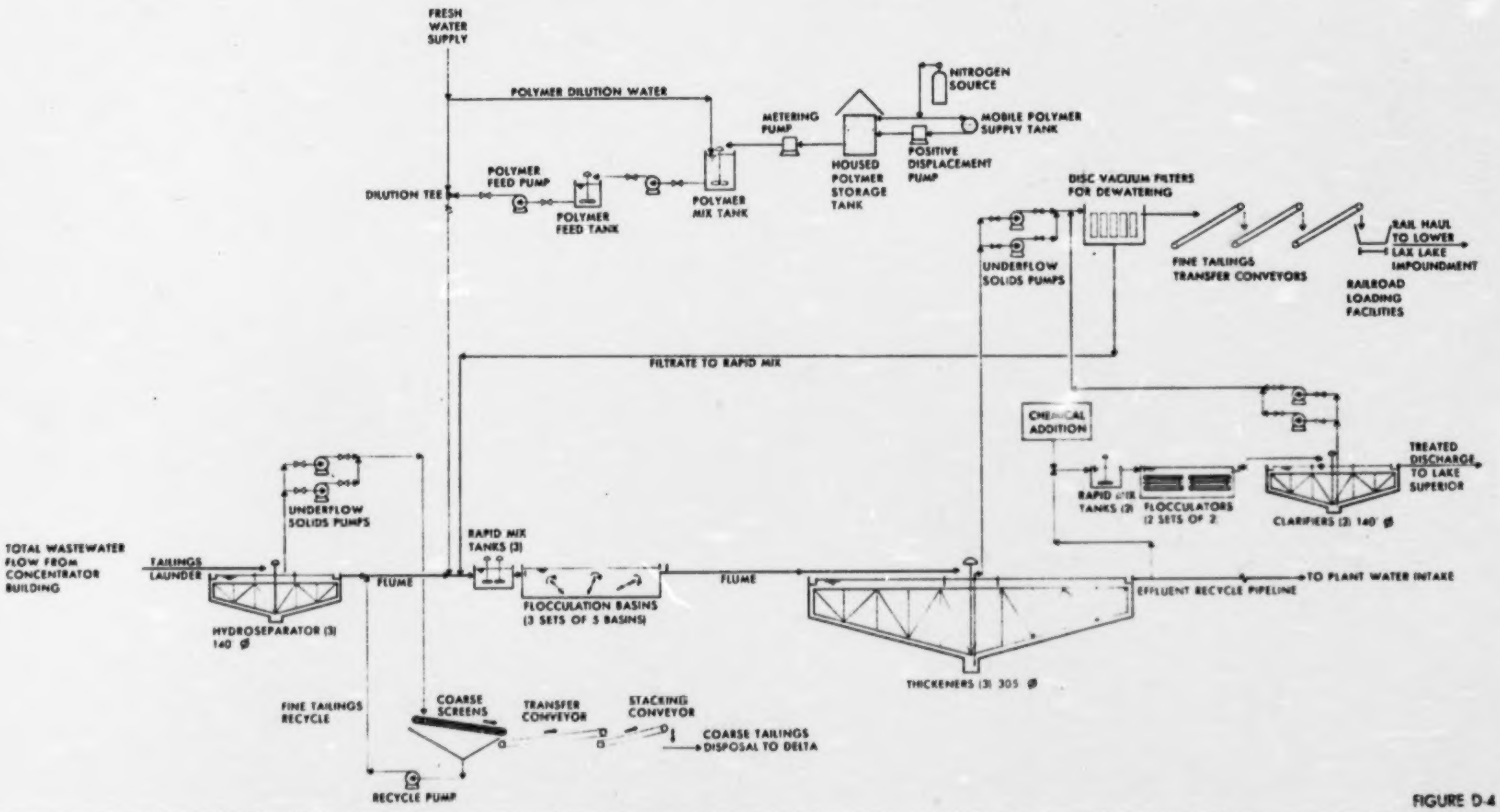
FRESH WATER SUPPLY
POLYMER DILUTION WATER
NITROGEN SOURCE
METERING PUMP
MOBILE POLYMER SUPPLY TANK
POSITIVE DISPLACEMENT PUMP
HOUSED POLYMER STORAGE TANK
DILUTION TEE
POLYMER FEED PUMP
POLYMER FEED TANK
POLYMER MIX TANK
DISC VACUUM FILTERS FOR DEWATERING
UNDERFLOW SOLIDS PUMPS
FINE TAILINGS TRANSFER CONVEYORS
RAIL HAUL TO LOWER LAX LAKE IMPOUNDMENT
RAILROAD LOADING FACILITIES
FILTRATE TO RAPID MIX
CHEMICAL ADDITION
TREATED DISCHARGE TO LAKE SUPERIOR
RAPID MIX TANKS (2)
FLOCCULATORS (2 SETS OF 2
CLARIFIERS (2) 140' Ø
UNDERFLOW SOLIDS PUMPS
TOTAL WASTEWATER FLOW FROM CONCENTRATOR BUILDING
TAILINGS LAUNDER
FLUME
RAPID MIX TANKS (3)
FLUME
TO PLANT WATER INTAKE
EFFLUENT RECYCLE PIPELINE
HYDROSEPARATOR (3) 140 Ø
FLOCCULATION BASINS (3 SETS OF 5 BASINS)
THICKENERS (3) 305 Ø
FINE TAILINGS RECYCLE
COARSE SCREENS
TRANSFER CONVEYOR
STACKING CONVEYOR
COARSE TAILINGS DISPOSAL TO DELTA
RECYCLE PUMP

FIGURE D-4

## Alternative No. 4

This alternative involves the on-site processing of concentrator plant wastewater for the removal of suspended solids. Coarse tailings are removed from the wastewater by Hydroseparators, dewatered and conveyed to the delta edge for disposal in Lake Superior. Fine tailings are flocculated with organic polymers and are subsequently removed from the wastewater using gravity thickeners. Thickened solids are pumped by overland pipeline to the Lower Lax Lake Area for on-land disposal.

### Description of Major Facilities

A preliminary flow diagram of the facilities proposed in Alternative No. 4 is shown on Figure D-5.

#### On-Site Processing

Concentrator wastewater would be diverted into realigned launders, which would carry the total plant flow to three 140'-diameter Hydroseparators. The West Launder would be intercepted upstream of the point where a flow of 120,000 gpm of fresh water is now added to flush the tailings to the delta. The elimination of this flushing water would reduce the hydraulic requirements of the treatment facility and also reduce the total pumping requirements of the Silver Bay Plant. The existing launders would be retained as emergency bypasses, but the West Launder would be relocated to make room for the treatment facility.

Hydroseparators would provide a separation at approximately 150 mesh. The underflow solids (>150-mesh) would be withdrawn by center-column pumping using three 4,500 gpm rubber-lined solids pumps and transported to screens prior to dewatering. Three standby pumps would be provided to insure continuous operation. Overflow from the Hydroseparators would flow to two of the three processing lines. One standby line is provided to maintain a continuous treatment operation in case of equipment failure.

Organic polymers would be added to the Hydroseparator overflow ahead of the rapid-mix tanks at a dosage rate of 2 mg/l. A 30,000-gallon rubber-lined tank housed in the control building would be used for bulk polymer storage. The polymer concentrate would be fed to a mix tank to prepare a 5 percent polymer solution. This solution would be transferred to the polymer feed tanks, from which it would be fed to the rapid-mix tanks.

The rapid-mix tanks would provide a detention time of 1 minute, with two units in operation to assure complete dispersion of the polymer. Wastewater would then flow to the flocculation basins to aid in the formation of the floc. Five rectangular flocculators in parallel, with a detention time of 10 minutes each, are provided for each process line to absorb the energy of the wastewater and prevent short-circuiting.

The flocculated wastewater would then flow to the center well of the 305'-diameter thickeners. The transport launders from the flocculation basins to the thickeners would provide an average flow velocity of 3 fps, to prevent the settling of solids in the launder, and to keep the floc from breaking up.

Flocculated fines would settle to the bottom of the thickeners and be collected at the center well for center-column pumping. This underflow would be removed at a concentration of 40 to 50 percent solids by one of two 5,000-gpm sludge pumps. A standby pump is provided to assure continuous operation.

Clarified effluent from the thickeners would be returned via two 60" concrete pipes to the plant's water intake located in the northwest corner of the harbor. The pipe walls would be coated to protect the pipe against velocities in excess of 15 fps.

### Water Treatment Plant

Gradual buildup in concentration of suspended and dissolved solids can result from the continuous recycle of process water. This is especially true during winter operation, when calcium chloride (used to prevent the ore from freezing in the railroad cars) finds its way into the process water. An excessive buildup of calcium in the process would interfere with the pelletizing process and would adversely affect final product quality. For this reason, a water treatment plant has been proposed to control the water quality. The water treatment plant would withdraw and treat a portion of the thickener overflow and an equal amount of "clean" harbor water would replace that portion withdrawn from this system for treatment. With this method of withdrawal and dilution, the solids buildup in the recycled process water can be controlled. The thickener overflow that is treated will require the removal of suspended solids prior to discharge into the lake. Little if any removal of dissolved solids can be expected in this treatment system

Research performed by the Reserve Mining Company (and reported in a memo from R.S. Lemire to K.M. Haley dated January 28, 1971) indicated that a withdrawal rate equal to seven percent of the total volume of process water could be expected to provide recycled process water of acceptable quality. For purposes of design, a flow equal to 8.5 percent of the design flow of 290,000 gpm was used to size the water treatment facilities. It should be noted, however, that this percentage figure should be verified through pilot plant testing before a final design is established.

Chemical flocculation would be used to treat the 25,000 gpm flow to be withdrawn from the thickener overflow. The flow would be split in half, and flow by gravity to two rapid-mix tanks. Addition for inorganic chemical and mixing would be performed prior to flocculation. Two rectangular flocculation basins are provided for each line to aid in the formation of flocculated solids. Approximately eight minutes of flocculation would be provided before the flow is discharged to the 140'-diameter clarifiers. The clarifiers would have a design overflow rate of 1,000 gpd/sq.ft. and provide a detention time of more than two hours. Overflow from these clarifiers would be discharged to Lake Superior through a sub-surface diffuser system. Underflow solids would be pumped through the center column of the clarifier and would be mixed and disposed of with the fine tailings.

### Tailings Transport

Underflow solids from the thickeners and sludge from the water treatment plant would be pumped to the slurry mix tank prior to pumping to the disposal area. The mixing tank would have a volume of 500,000, and a mixer would be provided to maintain the slurry solids in suspension.

The overland pipeline, which would transport the fine tailings to the Lower Lax Lake area impoundment basin would be fed by four 2,300-gpm positive-displacement pumps. A standby pump would also be available to provide continuity in the operation. These pumps would be capable of overcoming the 1,300-ft. total head differential which would exist between the delta pumping station and the impoundment area. For this reason, no intermediate pump stations would be required.

Coarse tailings removed from the wastewater as Hydroseparator underflow would be pumped to screens for dewatering. A 150-mesh separation would be provided so that fines (-150 mesh) trapped with the coarse solids could be removed and returned to the treatment process. The resulting dewatered coarse tailings with the fines removed would be discharged to conveyors and carried to the delta edge for in-lake disposal.

### On-Land Disposal

The on-land disposal of tailings is proposed for the low-land marshy area south of Lax Lake. This area (referred to as the Lower Lax Lake area) has ample capacity to store the estimated volume of tailings.

In previous studies, an emergency spillway was provided to release excess water captured in the basin. Additional freebroad was provided in some cases to contain wet-weather runoff in order to prevent overtopping the dam However, upstream diversion of the streams draining into the basin may be more economical and more reliable, and this latter approach is incorporated in the proposed site.

Six separate earthen-type dams, with a final elevation of 1,300 feet, are proposed for the basin. Figure 11 in Section V of the main report shows the proposed location for these embankments. Dam E is designed not only to contain the tailings but also to isolate the Lax Lake area, which appears to have some recreational and resort value to the surrounding region. The location of Dam E, however, will back up water into Fortythree Creek and eventually flood the Lax Lake area. To eliminate this, four 20-foot tunnels at location H have been proposed to provide a discharge for this water. These tunnels would handle the discharge from the East Branch of the Beaver River and Fortythree Creek. An additional diversion structure located at point G would direct Big Thirtynine Creek to the Beaver River. The only remaining stream flowing into the impoundment area would be Little Thirtynine Creek, which could be contained in the much smaller storage provided on the top of the tailings.

The dust problem that could result from wind action on the in-place tailings has been the cause of much concern. Planting and revegetation would be the final solution to dusting problems. For an interim measure, however, an inert encrustating agent could be applied to the dusting surface of the tailings to stabilize them The agent would be sprayed in dilute solutions upon the tailings to form a stable crust with a few inches of tailings. As long as the surface remains undisturbed, the crust would remain intact, thus minimizing the dust problem.

### Major Units

A summary list of the major units and equipment items, with the principal dimensional and capacity information, is presented in the following pages.

## SUMMARY OF MAJOR UNITS AND SIZES
## ALTERNATIVE NO. 4

| | |
|---|---|
| On-Site Processing | |
| Launder Realignment | |
| East Launder | |
| Length | 450' |
| Width | 20' |
| Height | 5' |
| Construction Material | Concrete w/steel plate |
| West Launder | |
| Length | 550' |
| Width | 20' |
| Height | 5' |
| Construction Material | Concrete w/steel plate |
| Hydroseparators | |
| Number | 3 |
| Diameter | 140' |
| Depth | 20' |
| Underflow pumps | |
| Number | 6 (including 2 standbys) |
| Capacity | 4,500 gpm, each |
| Type | Centrifugal, Variable-speed |
| Rapid-Mix Tanks | |
| Number | 3 (including 1 standby) |
| Volume | 150,000 gallons |
| Shape | Square |
| Dimensions | 24' x 49' x 15' SWD<br>+ 2' freeboard (fb.) |
| Detention Time | 60 seconds |
| Mixers | 6 (2 per tank) |
| Flocculator | |
| Sets | 3 (including 1 standby) |
| Tanks | 5 per set |
| Tank Dimensions | |
| Length | 140' |
| Width | 20' |
| SWD | 20' + 2' fb |
| Detention Time | 10 minutes |
| Mixers | |
| Number | 5 per tank (25 per set) |
| Type | Variable-speed |
| Maximum Speed | 50 rpm |
| Wastewater Launders (to Clarifiers) | |
| Number | 3 |
| Length | 300' (maximum) |
| Width | 15' |
| Height | 10' |
| Construction Material | Concrete w/steel plate |
| Thickeners | |
| Number | 3 |
| Type | Circular |
| Diameter | 305' |
| Depth | 20' SWD + 2' fb |
| Overflow rate | 3,000 gpd/sq.ft. |
| Construction Material | Concrete |
| Underflow Pumps | |
| Number | 6 (including 3 standbys) |
| Capacity | 5,000 gpm, each |
| Type | Centrifugal, Variable-speed |
| Operation | Center-Column Removal |
| Polymer Addition Facilities | |
| Bulk Storage Tank w/Nitrogen Seal | |
| Volume | 30,000 gallons |
| Material | Steel |

| | |
|---|---|
| Bulk Polymer Transfer Pump | |
| Number | 2 |
| Capacity | 50 gpm |
| Type | Gear |
| Polymer Mix Tank | |
| Number | 1 |
| Volume | 5,000 gallons |
| Type | Steel w/liner |
| Mixer Size | 3 HP |
| Bulk Polymer Pumps to Mix Tank | |
| Number | 2 |
| Capacity | 15 gpm |
| Type | Gear |
| Polymer Feed Pumps to Feed Tank | |
| Number | 2 |
| Capacity | 15 gpm |
| Type | Centrifugal |
| Polymer Feed Tanks | |
| Number | 2 |
| Volume | 5,000 gallons |
| Type | Steel w/liner and insulated |
| Mixer size (1 per tank) | 2 HP |
| Polymer Feed Pumps | |
| Number | 4 |
| Capacity (variable) | 10 to 15 gpm |
| Effluent Recycle Pipeline | |
| Length | 1,000' |
| Number | 2 |
| Diameter | 60" |
| Type | Concrete |
| Additional Requirements | Protective liner for velocities in excess of 15 fps. |
| Coarse Solids Dewatering | |
| Type | Double Screen |
| Number | 12 |
| Fine Screen Size | 150 mesh |
| Fine Solids Dewatering | |
| Type | Disc-vacuum filters |
| Number | 11 (including 2 standbys) |
| Disc Diameter | 9' |
| Discs per filter | 15 |
| Filter Yield | 150 lbs./sq.ft./hr. |
| Cake Moisture | 30 percent |
| Water Treatment Plant | |
| Rapid-Mix Tanks | |
| Number | 2 |
| Volume | 12,500 gallons |
| Dimensions | 13' x 13' x 10' SWD + 2' fb |
| Detention Time | 60 seconds |
| Type | Concrete |
| Mixers | 2 (1 per tank) |
| Flocculators | |
| Sets | 2 |
| Tanks per set | 2 |
| Tank Dimensions | |
| Length | 40' |
| Width | 15' |
| SWD | 15' + 2' fb |
| Dention Time | 10 minutes |
| Mixers | |
| Number | 8 (2 per tank) |
| Type | Variable-Speed |
| Maximum Speed | 50 rpm |
| Clarifiers | |
| Number | 2 |
| Type | Circular |

| | |
|---|---|
| Diameter | 140' |
| Depth | 15' SWD + 2' fb |
| Overflow Rate | 1,000 gpd/sq.ft. |
| Construction Material | Concrete |
| Underflow Pumps | |
| Number | 4 (2 are standbys) |
| Capacity | 10 gpm |
| Type | Centrifugal, Variable-speed |
| Operation | Center-Column Removal |
| Tailings Transport | |
| Course Solids Dewatering | |
| Type | Double Screen |
| Number | 12 |
| Fine Screen Size | 150 mesh |
| Course Tailings Conveyor to Delta | |
| Width | 42" |
| Length | 2,500' |
| Drop | 45' |
| Total Load | 2,000 STPH |

| | |
|---|---|
| Course Tailings Stacking Conveyor | |
| Width | 42' |
| Lift | 30' |
| Horizontal Reach | 400' |
| Type | Swivel Base |
| Fine Tailings Slurry Tank | |
| Number | 1 |
| Volume | 500,000 gallons |
| Length | 58' |
| Width | 58' |
| Depth | 20' + 2' fb |
| Material of Construction | Concrete |
| Mixer | 1 |
| Size | 250 HP |
| Fine Tailings Slurry Pumps | |
| Number | 5 |
| Type | Positive Displacement |
| Capacity | 2,300 gpm |
| Fine Tailings Pipelines | |
| Number | 2 |
| Length | 21,150' |
| Diameter | 14" |
| Minimum Velocity | 8 fps |

## Cost Estimates

Capital and Annual Cost estimates for the facilities and processes proposed for Alternative No. 4 are presented in Table D-4. The contingency provided in the total capital cost estimate includes professional services for design, plus an allowance for the escalation in prices that may occur by the time construction is started. The estimates of annual costs include both fixed costs (interest and depreciation over a 20-year period) and operating costs. Labor and Supervision costs have been based on the manning of four shifts (to cover 24-hour, 7-day operation), and on average rates of $5.00/hour for labor and $1,100/month for supervision. Electrical power cost estimates are based on operating horsepower requirements only, with a unit power cost of $0.012 per KW-HR.

Table D-4

## Alternative No. 4
## Coarse Tailings to Delta: Fine Tailings Pumped to Lower Lax Lake Area

### CAPITAL COST ESTIMATE

| | | |
|---|---|---|
| On-Site Processing | | |
| Launder Realignment | $ 590,000 | |
| Hydroseparators | 1,780,000 | |
| Rapid Mix Tank | 192,000 | |
| Flocculators | 1,795,000 | |
| Thickeners | 4,392,000 | |
| Polymer Addition | 208,000 | |
| Wastewater Transport Launders | 2,600,000 | |
| Treated Effluent Recycle | 318,000 | |
| Solids Dewatering - Coarse | 188,000 | |
| Site Work | 170,000 | |
| Piling | 1,236,000 | |
| Control Building | 932,000 | |
| Piping, Electrical, and Instrumentation | 5,408,000 | |
| Sub-Total | | $19,441,000 |
| Water Treatment | | |
| Rapid Mix Tanks | $ 26,000 | |
| Flocculation Tanks | 141,000 | |
| Chemical Addition Facilities | 15,000 | |
| Clarifiers | 933,000 | |
| Site Work | 8,000 | |
| Piping, Electrical, and Instrumentation | 394,000 | |
| Sub-Total | | 1,517,000 |
| Tailings Transport | | |
| Coarse Tailings Conveyors | $ 790,000 | |
| Fine Tailings Slurry Tank | 190,000 | |
| Fine Tailings Transport Pumps | 1,956,000 | |
| Fine Tailings Pipeline | 1,017,000 | |
| Sub-Total | | 3,953,000 |
| Disposal Site | | |
| Start Dam | $ 6,700,000 | |
| Diversion Dams and Channels | 10,317,000 | |
| Sub-Total | | 17,017,000 |
| Contingency at 15 percent | | 6,274,000 |
| TOTAL CAPITAL COST | | $48,102,000 |

### ANNUAL COST ESTIMATE

| | | |
|---|---|---|
| Operating Costs | | |
| Labor and Supervision | $ 1,490,000 | |
| Maintenance and Repair | 929,000 | |
| Utilities (Power and Fuel) | 633,000 | |
| Chemicals | 920,000 | |
| Dam Construction and Maintenance | 1,783,000 | |
| Sub-Total | | $ 5,755,000 |
| Fixed Costs | | |
| Interest | $ 2,165,000 | |
| Depreciation | 2,405,000 | |
| Sub-Total | | 4,570,000 |
| TOTAL ANNUAL COST | | $10,325,000 |

RESERVE MINING COMPANY
SILVER BAY, MINNESOTA
PROCESS FLOW DIAGRAM
PROPOSED WASTEWATER TREATMENT FACILITIES
ALTERNATIVE 4

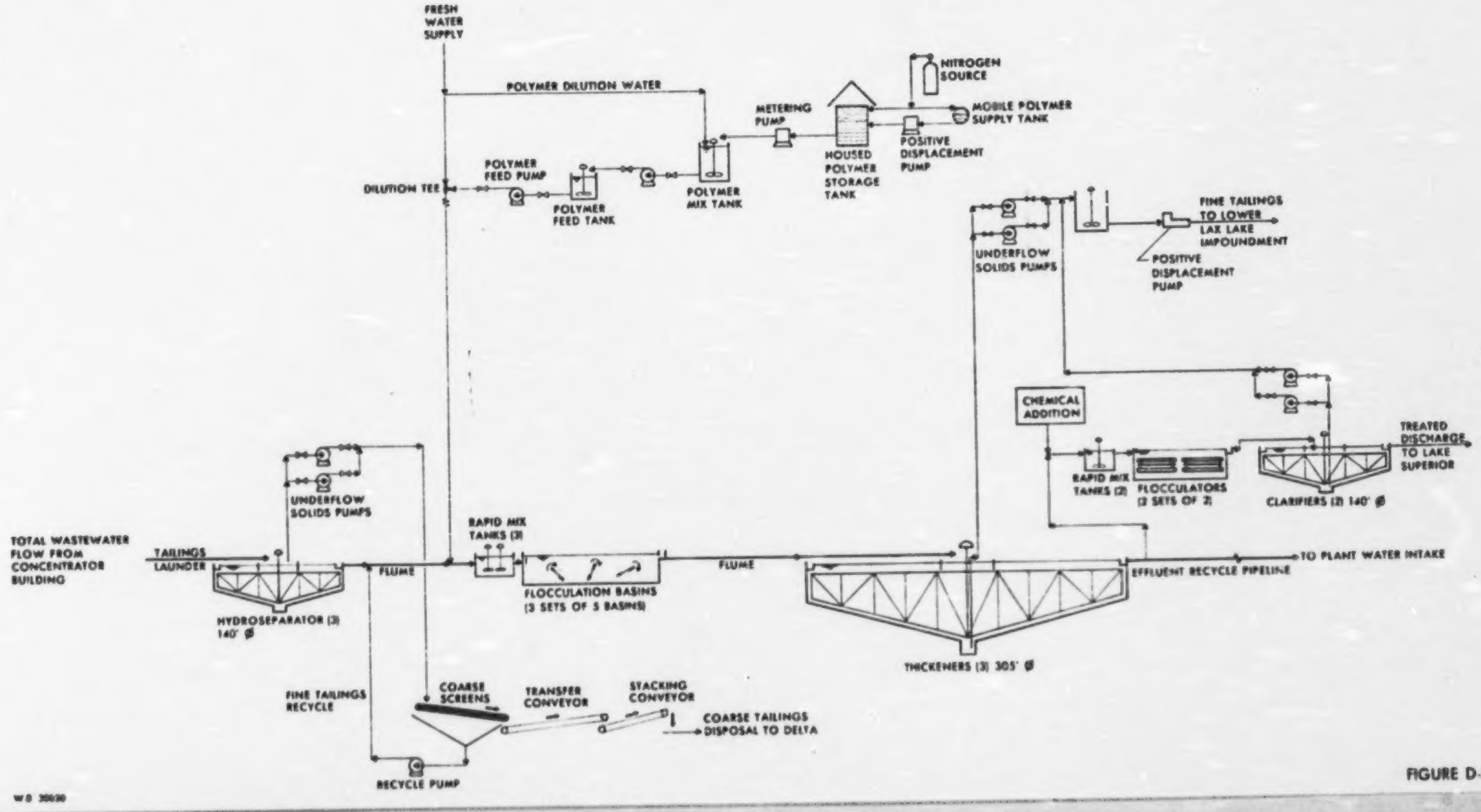
FRESH WATER SUPPLY
POLYMER DILUTION WATER
NITROGEN SOURCE
METERING PUMP
MOBILE POLYMER SUPPLY TANK
POSITIVE DISPLACEMENT PUMP
POLYMER FEED PUMP
DILUTION TEE
POLYMER FEED TANK
POLYMER MIX TANK
HOUSED POLYMER STORAGE TANK
FINE TAILINGS TO LOWER LAX LAKE IMPOUNDMENT
UNDERFLOW SOLIDS PUMPS
POSITIVE DISPLACEMENT PUMP
CHEMICAL ADDITION
TREATED DISCHARGE TO LAKE SUPERIOR
RAPID MIX TANKS (2)
FLOCCULATORS (2 SETS OF 2)
CLARIFIERS (2) 140' Ø
UNDERFLOW SOLIDS PUMPS
RAPID MIX TANKS (3)
TOTAL WASTEWATER FLOW FROM CONCENTRATOR BUILDING
TAILINGS LAUNDER
FLUME
FLOCCULATION BASINS (3 SETS OF 5 BASINS)
FLUME
EFFLUENT RECYCLE PIPELINE
TO PLANT WATER INTAKE
HYDROSEPARATOR (3) 140' Ø
THICKENERS (3) 305' Ø
FINE TAILINGS RECYCLE
COARSE SCREENS
TRANSFER CONVEYOR
STACKING CONVEYOR
COARSE TAILINGS DISPOSAL TO DELTA
RECYCLE PUMP
W O 20630

FIGURE D-5

## Alternative No. 5

This alternative involves the on-site processing of the concentrator plant wastewater for the removal of suspended solids. Coarse tailings would be removed from the wastewater by Hydroseparators and would be piped to a sub-surface discharge in Lake Superior. The fine tailings would be flocculated with organic polymers and subsequently would be removed from the wastewater by gravity thickeners. The thickened solids would be pumped by overland pipeline to the Lower Lax Lake area for on-land disposal.

### Description of Major Facilities

A preliminary flow diagram of the facilities proposed in Alternative No. 5 is shown in Figure D-6.

#### On-Site Processing

Concentrator wastewater would be diverted into realigned launders, which would carry the total plant flow to three 140'-diameter Hydroseparators. The West Launder would be intercepted upstream of the point where a flow of 120,000 gpm of fresh water is now added to flush the tailings to the delta. The elimination of this flushing water would reduce the hydraulic requirements of the treatment facility and also reduce the total pumping requirements of the Silver Bay Plant. The existing launders would be retained as emergency bypasses, but the West Launder would be relocated to make room for the treatment facility.

Hydroseparators would provide a separation at approximately 150 mesh. The underflow solids (>150-mesh) would be withdrawn by center-column pumping using three 4,500 gpm rubber-lined solids pumps and transported to screens prior to dewatering. Three standby pumps would be provided to insure continuous operation. Overflow from the Hydroseparators would flow to two of the three processing lines. One standby line is provided to maintain a continuous treatment operation in case of equipment failure.

Organic polymers would be added to the Hydroseparator overflow ahead of the rapid-mix tanks at a dosage rate of 2 mg/l. A 30,000-gallon rubber-lined tank housed in the control building would be used for bulk polymer storage. The polymer concentrate would be fed to a mix tank to prepare a 5 percent polymer solution. This solution would be transferred to the polymer feed tanks, from which it would be fed to the rapid-mix tanks.

The rapid-mix tanks would provide a detention time of 1 minute, with two units in operation to assure complete dispersion of the polymer. Wastewater would then flow to the flocculation basins to aid in the formation of the floc. Five rectangular flocculators in parallel, with a detention time of 10 minutes each, are provided for each process line to absorb the energy of the wastewater and prevent short-circuiting.

The flocculated wastewater would then flow to the center well of the 305'-diameter thickeners. The transport launders from the flocculation basins to the thickeners would provide an average flow velocity of 3 fps, to prevent the settling of solids in the launder, and to keep the floc from breaking up.

Flocculated fines would settle to the bottom of the thickeners and be collected at the center well for center-column pumping. This underflow would be removed at a concentration of 40 to 50 percent solids by one of two 5,000-gpm sludge pumps. A standby pump is provided to assure continuous operation.

Clarified effluent from the thickeners would be returned via two 60" concrete pipes to the plant's water intake located in the northwest corner of the harbor. The pipe walls would be coated to protect the pipe against velocities in excess of 15 fps.

### Water Treatment Plant

Gradual buildup in concentration of suspended and dissolved solids can result from the continuous recycle of process water. This is especially true during winter operation, when calcium chloride (used to prevent the ore from freezing in the railroad cars) finds its way into the process water. An excessive buildup of calcium in the process would interfere with the pelletizing process and would adversely affect final product quality. For this reason, a water treatment plant has been proposed to control the water quality. The water treatment plant would withdraw and treat a portion of the thickener overflow and an equal amount of "clean" harbor water would replace that portion withdrawn from this system for treatment. With this method of withdrawal and dilution, the solids buildup in the recycled process water can be controlled. The thickener overflow that is treated will require the removal of suspended solids prior to discharge into the lake. Little if any removal of dissolved solids can be expected in this treatment system

Research performed by the Reserve Mining Company (and reported in a memo from R.S. Lemire to K.M. Haley dated January 28, 1971) indicated that a withdrawal rate equal to seven percent of the total volume of process water could be expected to provide recycled process water of acceptable quality. For purposes of design, a flow equal to 8.5 percent of the design flow of 290,000 gpm was used to size the water treatment facilities. It should be noted, however, that this percentage figure should be verified through pilot plant testing before a final design is established.

Chemical flocculation would be used to treat the 25,000 gpm flow to be withdrawn from the thickener overflow. The flow would be split in half, and flow by gravity to two rapid-mix tanks. Addition for inorganic chemical and mixing would be performed prior to flocculation. Two rectangular flocculation basins are provided for each line to aid in the formation of flocculated solids. Approximately eight minutes of flocculation would be provided before the flow is discharged to the 140'-diameter clarifiers. The clarifiers would have a design overflow rate of 1,000 gpd/sq.ft. and provide a detention time of more than two hours. Overflow from these clarifiers would be discharged to Lake Superior through a sub-surface diffuser system. Underflow solids would be pumped through the center column of the clarifier and would be mixed and disposed of with the fine tailings.

### Tailings Transport

Underflow solids from the thickeners would be pumped to the slurry mix tank prior to pumping to the disposal area. The mix tank would have an approximate volume of 500,000 gallons, and a mixer would be provided to maintain the slurry solids in suspension.

The overland pipeline, which would transport the fine tailings to the Lower Lax Lake impoundment basin, would be fed by four 2,300-gpm positive-displacement pumps. A standby pump would also be available to provide continuity in the operation. These pumps would be capable of overcoming the 1,300-ft. total head differential, which would exist between the delta pumping station and the impoundment area. Therefore, no intermediate pumping stations would be required.

The coarse solids in the Hydroseparator underflow would be dewatered using screens with a minimum sieve size of 150 mesh. The solids (-150 mesh) would be washed through the tailings with the filtrate and returned to the treatment process. Dewatered and washed coarse tailings would then be conveyed to a reslurry tank prior to pumping to Lake Superior.

In the reslurry tank, fresh lake water would be mixed with the coarse tailings to resuspend the tailings. A mixer would be required to keep the solids from settling. The tailings would be pumped in a 30-percent slurry to a discharge point approximately 150' below the surface of Lake Superior. Two 20" pipelines would be used to transport the coarse tailings.

### On-Land Disposal

The on-land disposal of tailings is proposed for the low-land marshy area south of Lax Lake. This area (referred to as the Lower Lax Lake area) has ample capacity to store the estimated volume of tailings.

In previous studies, an emergency spillway was provided to release excess water captured in the basin. Additional freebroad was provided in some cases to contain wet-weather runoff in order to prevent overtopping the dam However, upstream diversion of the streams draining into the basin may be more economical and more reliable, and this latter approach is incorporated in the proposed site.

Six separate earthen-type dams, with a final elevation of 1,300 feet, are proposed for the basin. Figure 11 in Section V of the main report shows the proposed location for these embankments. Dam E is designed not only to contain the tailings but also to isolate the Lax Lake area, which appears to have some recreational and resort value to the surrounding region. The location of Dam E, however, will back up water into Fortythree Creek and eventually flood the Lax Lake area. To eliminate this, four 20-foot tunnels at location H have been proposed to provide a discharge for this water. These tunnels would handle the discharge from the East Branch of the Beaver River and Fortythree Creek. An additional diversion structure located at point G would direct Big Thirtynine Creek to the Beaver River. The only remaining stream flowing into the impoundment area would be Little Thirtynine Creek, which could be contained in the much smaller storage provided on the top of the tailings.

The dust problem that could result from wind action on the in-place tailings has been the cause of much concern. Planting and revegetation would be the final solution to dusting problems. For an interim measure, however, an inert encrustating agent could be applied to the dusting surface of the tailings to stabilize them. The agent would be sprayed in dilute solutions upon the tailings to form a stable crust with a few inches of tailings. As long as the surface remains undisturbed, the crust would remain intact, thus minimizing the dust problem.

### Major Units

A summary list of the major units and equipment items with the principal dimensional and capacity information, is presented in the following pages.

## SUMMARY OF MAJOR UNITS AND SIZES
## ALTERNATIVE NO. 5

| | |
|---|---|
| **On-Site Processing** | |
| Launder Realignment | |
| East Launder | |
| Length | 450' |
| Width | 20' |
| Height | 5' |
| Construction Material | Concrete w/steel plate |
| West Launder | |
| Length | 550' |
| Width | 20' |
| Height | 5' |
| Construction Material | Concrete w/steel plate |
| Hydroseparators | |
| Number | 3 |
| Diameter | 140' |
| Depth | 20' |
| Underflow pumps | |
| Number | 6 (including 2 standbys) |
| Capacity | 4,500 gpm, each |
| Type | Centrifugal, Variable-speed |
| Rapid Mix Tanks | |
| Number | 3 (including 1 standby) |
| Volume | 150,000 gallons |
| Shape | Square |
| Dimensions | 24' x 49' x 15' SWD +2' freeboard (fb) |
| Detention Time | 60 seconds |
| Mixers | 6 (2 per tank) |
| Flocculator | |
| Sets | 3 (including 1 standby) |
| Tanks | 5 per set |
| Tank Dimensions | |
| Length | 140' |
| Width | 20' |
| SWD | 20' + 2' fb |
| Detention Time | 10 minutes |
| Mixers | |
| Numbers | 5 per tank (25 per set) |
| Type | Variable-speed |
| Maximum Speed | 50 rpm |
| Wastewater Launders (to Clarifiers) | |
| Number | 3 |
| Length | 300' (maximum) |
| Width | 15' |
| Height | 10' |
| Construction Material | Concrete w/steel plate |
| Thickeners | |
| Number | 3 |
| Type | Circular |
| Diameter | 305' |
| Depth | 20' SWD + 2' fb |
| Overflow rate | 3,000 gpd/sq.ft. |
| Construction Material | Concrete |
| Underflow Pumps | |
| Number | 6 (including 3 standbys) |
| Capacity | 5,000 gpm, each |
| Type | Centrifugal, Variable-speed |
| Operation | Center-Column Removal |
| Polymer Addition Facilities | |
| Bulk Storage Tank w/Nitrogen Seal | |
| Volume | 30,000 gallons |
| Material | Steel |
| Bulk Polymer Transfer Pump | |
| Number | 2 |
| Capacity | 50 gpm |
| Type | Gear |
| Polymer Mix Tank | |
| Number | 1 |
| Volume | 5,000 gallons |
| Type | Steel w/liner |
| Mixer Size | 3 HP |
| Bulk Polymer Pumps to Mix Tank | |
| Number | 2 |
| Capacity | 15 gpm |
| Type | Gear |
| Polymer Feed Pumps to Feed Tank | |
| Number | 2 |
| Capacity | 15 gpm |
| Type | Centrifugal |
| Polymer Feed Tanks | |
| Number | 2 |
| Volume | 5,000 gallons |
| Type | Steel w/liner and insulated |
| Mixer Size (1 per tank) | 2 HP |
| Polymer Feed Pumps | |
| Number | 4 |
| Capacity (variable) | 10 to 15 gpm |
| Effluent Recycle Pipeline | |
| Length | 1,000' |
| Number | 2 |
| Diameter | 60" |
| Type | Concrete |
| Additional Requirements | Protective liner for velocities in excess of 15 fps. |
| Coarse Solids Dewatering | |
| Type | Double Screen |
| Number | 12 |
| Fine Screen Size | 150 mesh |
| Fine Solids Dewatering | |
| Type | Disc-vacuum filters |
| Number | 11 (including 2 standby) |
| Disc Diameter | 9' |
| Discs per filter | 15 |
| Filter Yield | 150 lbs./sq.ft. hr. |
| Cake Moisture | 30 percent |
| **Water Treatment Plant** | |
| Rapid-Mix Tanks | |
| Number | 2 |
| Volume | 12,500 gallons |
| Dimensions | 13' x 13' x 10' SWD + 2' fb |
| Detention Time | 60 seconds |
| Type | Concrete |
| Mixers | 2 (1 per tank) |
| Flocculators | |
| Sets | 2 |
| Tanks per set | 2 |
| Tank Dimensions | |
| Length | 40' |
| Width | 15' |
| SWD | 15' + 2' fb |
| Detention Time | 10 minutes |
| Mixers | |
| Number | 8 (2 per tank) |
| Type | Variable-speed |
| Maximum Speed | 50 rpm |
| Clarifiers | |
| Number | 2 |
| Type | Circular |
| Diameter | 140' |
| Depth | 15' SWD + 2' fb |

| | |
|---|---|
| Overflow Rate | 1,000 gpd/sq.ft. |
| Construction Material | Concrete |

**Underflow Pumps**

| | |
|---|---|
| Number | 4 (2 are standby) |
| Capacity | 10 gpm |
| Type | Centrifugal, Variable-speed |
| Operation | Center-Column Removal |

**Tailings Transport**

**Fine Tailings Slurry Tank**

| | |
|---|---|
| Number | 1 |
| Volume | 500,000 gallons |
| Length | 58' |
| Width | 58' |
| Depth | 20' + 2' fb. |
| Material of Construction | Concrete |
| Mixer | 1 |
| Size | 250 HP |

**Fine Tailings Slurry Pump**

| | |
|---|---|
| Number | 5 (including 1 standby) |
| Type | Positive Displacement |
| Capacity | 2,300 gpm |

**Fine Tailings Pipeline**

| | |
|---|---|
| Number | 2 |
| Length | 21,150' |
| Diameter | 14" |
| Minimum Velocity | 8 fps. |

**Coarse Solids Dewatering**

| | |
|---|---|
| Type | Double Screen |
| Number | 12 |
| Fine Screen Size | 150-mesh |

**Coarse Solids Slurry Tank**

| | |
|---|---|
| Number | 1 |
| Volume | 315,000 gallons |
| Dimensions | 46' x 46' x 20' SWD + 3' fb. |
| Mixer | 1 |
| Size | 250 HP |

**Fresh Water Pump**

| | |
|---|---|
| Number | 3 |
| Type | Centrifugal |
| Capacity | 10,000 gpm |

**Coarse Solids Slurry Pumps**

| | |
|---|---|
| Number | 4 |
| Type | 2 constant-speed<br>2 variable-speed |
| Capacity | 7,000 gpm (each) |

**Coarse Slurry Pipelines**

| | |
|---|---|
| Number | 2 |
| Diameter | 20" |
| Length | 2,700' |

## Cost Estimates

Capital and Annual Cost estimates for the facilities and processes proposed for Alternative No. 5 are presented in Table D-5. The contingency provided in the total capital cost estimate includes professional services for design, plus an allowance for the escalation in prices that may occur by the time construction is started. The estimates of annual costs include both fixed costs (interest and depreciation over a 20-year period) and operating costs. Labor and Supervision costs have been based on the manning of four shifts (to cover 24-hour, 7-day operation), and on average rates of $5.00/hour for labor and $1,100/month for supervision. Electrical power cost estimates are based on operating horsepower requirements only, with a unit power cost of $0.012 per KW-HR.

## Table D-5

### Alternative No. 5
### Coarse Tailings Piped to Lake Superior
### Fine Tailings Pumped to Lower Lax Lake

### CAPITAL COST ESTIMATE

| | | |
|---|---|---|
| **On-Site Processing** | | |
| Launder Realignment | $ 590,000 | |
| Hydroseparators | 1,780,000 | |
| Rapid Mix Tank | 192,000 | |
| Flocculators | 1,795,000 | |
| Thickeners | 4,392,000 | |
| Polymer Addition | 208,000 | |
| Wastewater Transport Launders | 2,600,000 | |
| Treated Effluent Recycle | 318,000 | |
| Solids Dewatering - Coarse | 188,000 | |
| Site Work | 170,000 | |
| Piling | 1,236,000 | |
| Control Building | 932,000 | |
| Piping, Electrical, and Instrumentation | 5,040,000 | |
| Sub-Total | | $19,441,000 |
| **Water Treatment** | | |
| Rapid Mix Tanks | $ 26,000 | |
| Flocculation Tanks | 141,000 | |
| Chemical Addition Facilities | 15,000 | |
| Clarifiers | 933,000 | |
| Site Work | 8,000 | |
| Pipi[illegible] Electrical, and Instrumentation | 394,000 | |
| Sub-Total | | 1,517,000 |
| **Tailings Transport** | | |
| Coarse Tailings Pipeline and Outlet | $ 956,000 | |
| Fine Tailings Pump House | 190,000 | |
| Fine Tailings Transport Pumps | 1,956,000 | |
| Fine Tailings Pipeline | 1,017,000 | |
| Sub-Total | | 4,119,000 |
| **Disposal Site** | | |
| Starter Dam | $ 6,700,000 | |
| Diversion Dams and Channels | 10,317,000 | |
| Sub-Total | | 17,017,000 |
| Contingency at 15 percent | | 6,314,000 |
| **TOTAL CAPITAL COST** | | $48,408,000 |

### ANNUAL COST ESTIMATE

| | | |
|---|---|---|
| **Operating Costs** | | |
| Labor and Supervision | $ 1,546,000 | |
| Maintenance and Repair | 1,071,000 | |
| Utilities (Power and Fuel) | 685,000 | |
| Chemicals | 920,000 | |
| Dam Construction and Maintenance | 1,783,000 | |
| Sub-Total | | $ 6,005,000 |
| **Fixed Costs** | | |
| Depreciation | $ 2,420,000 | |
| Interest | 1,972,000 | |
| Sub-Total | | 4,392,000 |
| **TOTAL ANNUAL COST** | | $10,397,000 |

## RESERVE MINING COMPANY
SILVER BAY, MINNESOTA
PROCESS FLOW DIAGRAM
PROPOSED WASTEWATER TREATMENT FACILITIES
ALTERNATIVE 5

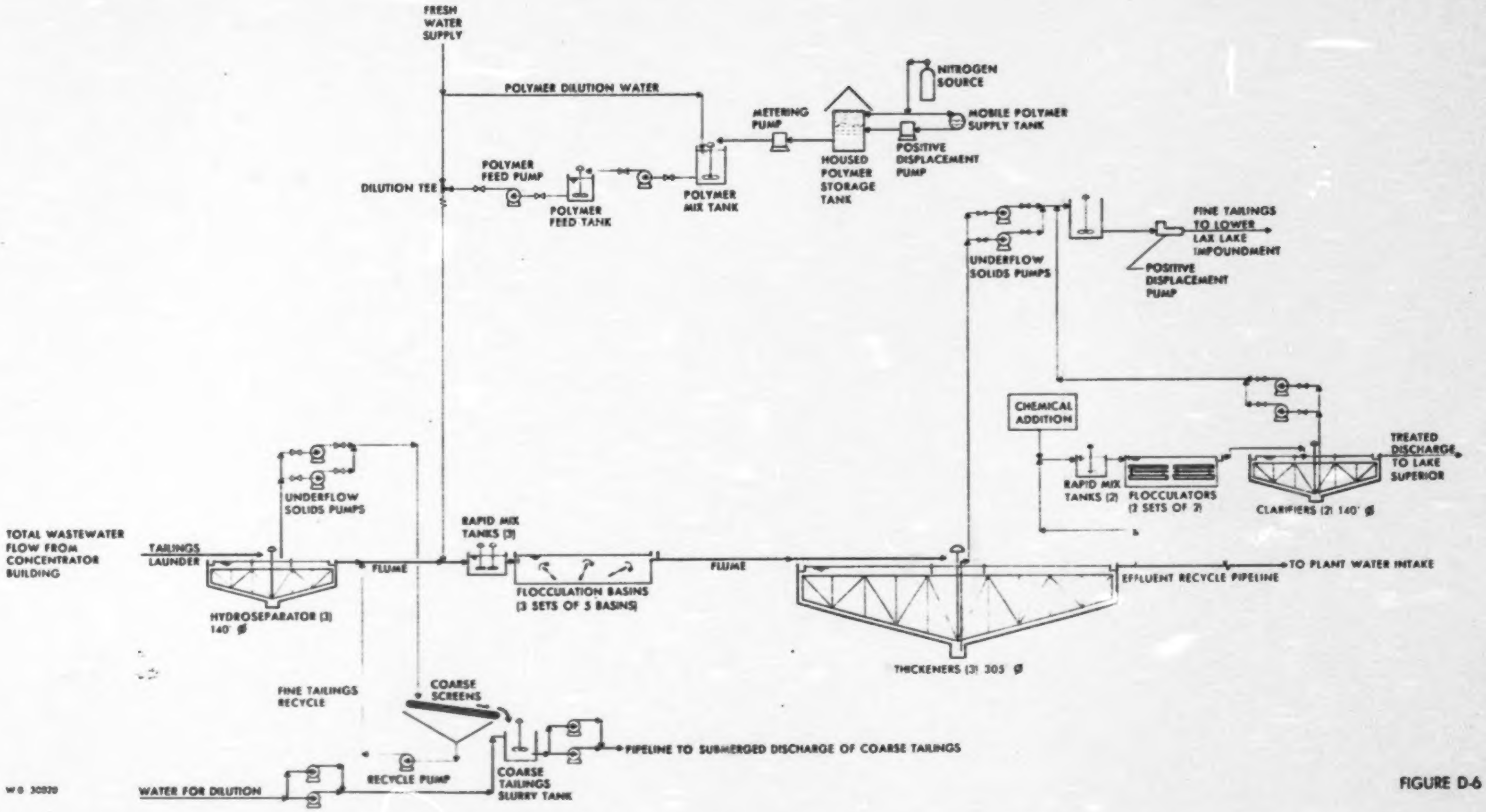
FRESH WATER SUPPLY
POLYMER DILUTION WATER
DILUTION TEE
POLYMER FEED PUMP
POLYMER FEED TANK
POLYMER MIX TANK
METERING PUMP
HOUSED POLYMER STORAGE TANK
NITROGEN SOURCE
MOBILE POLYMER SUPPLY TANK
POSITIVE DISPLACEMENT PUMP
UNDERFLOW SOLIDS PUMPS
FINE TAILINGS TO LOWER LAX LAKE IMPOUNDMENT
POSITIVE DISPLACEMENT PUMP
CHEMICAL ADDITION
RAPID MIX TANKS (2)
FLOCCULATORS (2 SETS OF 2)
CLARIFIERS (2) 140' Ø
TREATED DISCHARGE TO LAKE SUPERIOR
TOTAL WASTEWATER FLOW FROM CONCENTRATOR BUILDING
TAILINGS LAUNDER
UNDERFLOW SOLIDS PUMPS
HYDROSEPARATOR (3) 140' Ø
FLUME
RAPID MIX TANKS (3)
FLOCCULATION BASINS (3 SETS OF 5 BASINS)
FLUME
THICKENERS (3) 305' Ø
EFFLUENT RECYCLE PIPELINE
TO PLANT WATER INTAKE
FINE TAILINGS RECYCLE
COARSE SCREENS
RECYCLE PUMP
COARSE TAILINGS SLURRY TANK
PIPELINE TO SUBMERGED DISCHARGE OF COARSE TAILINGS
WATER FOR DILUTION
W 0 30020

FIGURE D-6

# APPENDIX E

## SPECIFIC STANDARDS OF QUALITY AND PURITY FOR LAKE SUPERIOR[1]

### Domestic Consumption

| Substance or Characteristics | Limit or Range |
|---|---|
| Total coliform organisms | 50 most probable number per 100 milliliters |
| Turbidity value | 5 |
| Color value | 15 |
| Threshold odor number | 3 |
| Methylene blue active substance (MBAS) | 0.5 milligram per liter |
| Arsenic (As) | 0.01 milligram per liter |
| Chlorides (Cl) | 250 milligrams per liter |
| Copper (Cu) | 1 milligram per liter |
| Carbon Chloroform extract | 0.2 milligram per liter |
| Cyanides (CN) | 0.01 milligram per liter |
| Fluorides (F) | 1.5 milligrams per liter |
| Iron (Fe) | 0.3 milligram per liter |
| Manganese (Mn) | 0.05 milligram per liter |
| Nitrates ($NO_3$) | 45 milligrams per liter |
| Phenol | 0.001 milligram per liter |
| Sulfates ($SO_4$) | 250 milligrams per liter |
| Total dissolved solids | 500 milligrams per liter |
| Zinc (Zn) | 5 milligrams per liter |
| Barium (Ba) | 1 milligram per liter |
| Cadmium (Cd) | 0.01 milligram per liter |
| Chromium (Hexavalent, Cr) | 0.05 milligram per liter |
| Lead (Pb) | 0.05 milligram per liter |
| Selenium (Se) | 0.01 milligram per liter |
| Silver (Ag) | 0.05 milligram per liter |

### Fisheries and Recreation

| | |
|---|---|
| Dissolved oxygen | Not less than 7 milligrams per liter from October 1st and continuing through May 31st, and<br>Not less than 5 milligrams per liter at other times |
| Temperature | No material increase |
| Ammonia (N) | Not to exceed a trace |
| Chlorides (Cl) | 50 milligrams per liter |
| Chromium (Cr) | Not to exceed a trace - mg/l[2] |

---

[1] Where a given parameter is listed in more than one category, the most restrictive limit or range applies.

[2] "Not to exceed a trace" value as defined by the Minnesota Pollution Control Agency. See letter attached.

## Fisheries and Recreation (continued)

| Substance or Characteristic | Limit or Range |
|---|---|
| Copper (Cu) | Not to exceed a trace - mg/l |
| Cyanides (CN) | Not to exceed a trace - mg/l |
| Oil | Not to exceed a trace - mg/l |
| pH value | 6.5 - 8.5 |
| Phenols | Not to exceed a trace - mg/l |
| Turbidity value | 10 |
| Color value | 30 |
| Total coliform organisms | 1,000 most probable number per 100 milliliters |
| Radioactive materials | Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use. |

## Industrial Consumption

| | | |
|---|---|---|
| Chlorides (Cl) | 50 milligrams per liter | |
| Hardness | 50 milligrams per liter | |
| pH value | 6.5 - 8.5 | |
| Temperature | 75°F in July and August,<br>70°F in June and September,<br>60°F in May and October,<br>50°F in April and November,<br>40°F in March and December,<br>and<br>35°F in January and February | (Surface) |
| | 55°F | (Ground) |
| Total coliform organisms | 5,000 most probable number per 100 milliliters | |

STATE OF MINNESOTA
POLLUTION CONTROL AGENCY
717 Delaware Street S.E.
(Oak and Delaware Streets S.E.)
Minneapolis 55440
612-378-1320

May 25, 1971

Mr. Louis J. Breimhurst
Acting Director
Water Quality Office
Environmental Protection Agency
7401 Lyndale Avenue South
Minneapolis, Minnesota 55423

Dear Mr. Breimhurst:

In regard to your letter of May 17, 1971, we have the following comments to make:

The phrase "not to exceed a trace" should be defined as: the lowest detectable concentration of a pollutant as determined by analysis on a routine basis at the time the standard was established.

The appropriate numerical values for the various parameters in WPC 15 with limits listed as "not to exceed a trace" would be on the basis of our 1967 routine water quality monitoring program as follows:

| | |
|---|---|
| Ammonia – N | 0.05 mg/l |
| Total Chromium | 0.02 mg/l |
| Copper | 0.01 mg/l |
| Cyanides | 0.05 micrograms/l |
| Oil | 0.30 mg/l |
| Phenols | 0.01 mg/l |

If you have any further questions, please contact us.

Yours very truly,

Dennis Anderson, Acting Chief
Section of Standards and Surveys

RDA:jsa